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T. Johannessen

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THESIS IN FISHERIES BIOLOGY

BY

TORE JOHANNESEN

INSTITUTE FOR FISHERIES BIOLOGY
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PREFACE

This thesis is part of Project 661.8 - 1 "Catch efficiency and selection in the longline fishery as a function of hook, bait and rigging" at the Institute for Fishery Technology, Harvesting Division in Bergen (FTFI). Funds for equipment and field trials have been made available by FTFI and the Fund for Exploratory Fishing and Research (FFFF).

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1. INTRODUCTION

The development of modern population dynamics in (p.6) research has shown that it is of essential importance to protect young, immature fish (GULLAND 1977). In order to manage the resources in a sensible way it is therefore necessary to have knowledge of how various gear parameters affect the length distribution of the catch.

Up to now most of the work has been concentrated on trawling gear and especially on how mesh sizes in the codend affect selectivity (POPE *et al* 1975). In addition there have also been a number of studies on gillnet selectivity (OLSEN 1959, HOLT 1963, HAMLEY 1975), while there are very few published studies with respect to other gear types.

Longline studies have been concentrated on giving useful measures for catch per unit effort (CPUE). Most of these studies are of a theoretical nature. Before the early 1950's it was assumed that the effort was directly proportional to the number of hooks. Later more refined catch comparisons have been developed taking into consideration saturation (GULLAND 1955, BEVERTON & HOLT 1957), loss of bait (MURHY 1960, SHEPARD *et al* 1975), soak time (SIVASUBRAMANIAM 1961), competition between various species (ROTHSCHILD 1967, RICKER 1975) and catch area (EGGERS *et al* 1982). Today CPUE is used, for example, in the management of tuna stocks (*Thunnus* spp) (ROTHSCHILD & SUDA 1977) and the stock of Pacific halibut (*Hippoglossus stenolepis*) (SKUD & HAMLEY 1978).

There are very few published works dealing with hook selectivity. In addition, they are at times contradictory. ROLLEFSEN (1953) reported that spawning cod caught on longline in Lofoten were smaller than those caught with purse seines, while the opposite has been demonstrated for tuna (ROTSCHILD & SUDA 1977) and Pacific salmon (*Oncorhynchus* spp) (FRENCH 1969). The selectivity curve calculated on the basis of ROLLEFSEN's data (under the assumption that the length distribution in the purse seine (p.7) catches are representative for the population), declines towards zero with in increasing length of the cod. However, McCRACKEN (1963) and SÆTERSDAL (1963) reported that the selection curve for cod is sigmoidal, and that the effectiveness is constant for fish above a certain length. RALSTON (1982) found that a sigmoid selectivity curve can best describe the selectivity in the jig fishery for various deep-sea species off Hawaii. ALLEN (1963) concluded that in some water courses the sports fishery for New Zealand trout is non-selective, while Japanese researchers (KOIKE et al 1968, KOIKE & KANDA 1978) found two-sided, flat-topped selectivity curves for various gear using hooks.

Actual parameters that can influence the selectivity of longlines and other hooked gear are listed by CLARK (1960) and POPE (1966). Both authors mention the hook as the assumed most important parameter, but that the bait is probably also of importance. Japanese researchers (op cit) reported that large hooks caught larger fish that small hooks. AASEN (1965) found that in the longline fishery for dogfish the hook size influenced both catch rate and the length distribution of the catch, but that there was no systematic correlation with respect to large hooks catching larger fish than smaller hooks. RALSTON (op cit) found, however, that different hook sizes were just as effective and that they had the same selective properties. A number of authors have reported that by changing the shape of the hook, catch rates higher than those with more conventional hooks were achieved (HAMRE 1968, FORSTER 1973, KARLSEN 1977, HUSE 1979a, 1979b, BJORDAL 1981a, 1981b, 1981c, 1982).

Very little has been done with respect to the effect of the bait size on selectivity. There is a widespread belief among fishermen that the bait size must be adapted to the size of the hook. This was used by McCRACKEN (1963) as a starting point in studies of the effect of hook- and bait size on the selectivity in the longline fishery for cod and haddock. He found that the combination of small hooks and small baits caught more small fish than the combination large hooks and large baits, but that the combinations were equally effective for fish over a certain (p.8) length. **KUROGANE** (1968) reported that, in the bottom longline fishery for various species in the Pacific, large baits caught larger fish than small baits. **KARLSEN** (1977) found that in the mid- and offshore ("bank") longline fishery for ling and cusk there was a tendency towards higher catch rates with increasing bait sizes than the standard bait size, while **BJORDAL** (1982) reported, however, that half size bait led to higher catch rates of ling.

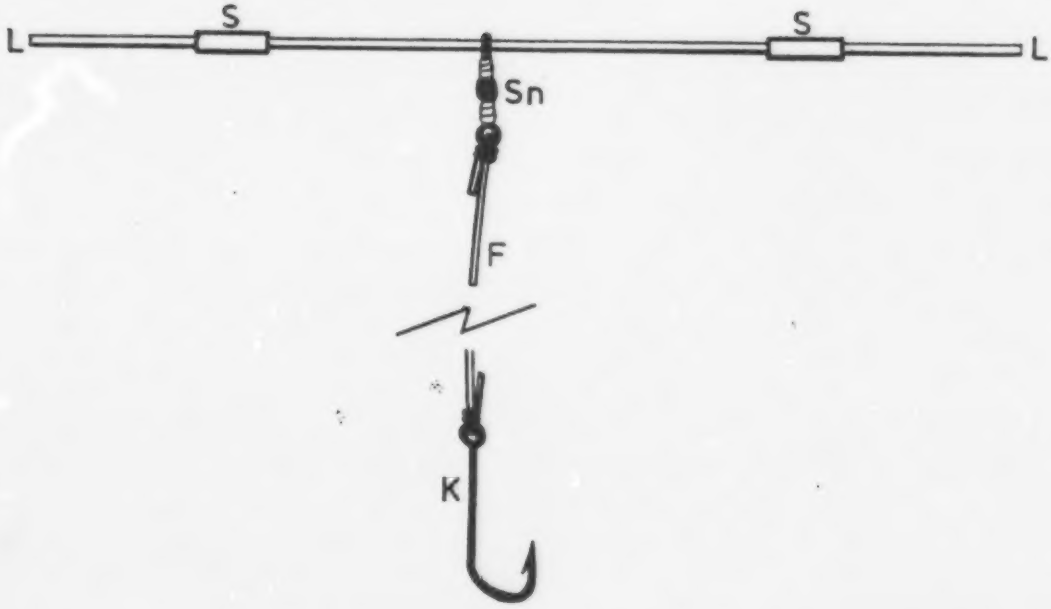
It can be seen from this brief literature review of hooked gear that there are some contradictory results. **BJORDAL** (1982) has in this connection pointed out that the experimental setup or protocol in comparative fishing trials could be a possible source of error in longline studies.

The objective of this thesis can be briefly summarized in two points:

1. To study the importance of various hook- and bait sizes on catching efficiency and length selection in the longline fishery for cod and haddock.

2. To evaluate different forms of experimental setups in longline fishing trials.

The objectives are attempted to be met through fishing trials at sea and through direct observations of fish behaviour towards hooks and baits in the laboratory.



Figur 2.1.1. Rigging av monofilamentline. L) Linerygg, S) stopper, Sn) snuer, F) forsyn, K) krok.

Figure 2.1.1. Rigging of monofilament line. L) Main line Sn) swivel, F) gangion, K) hook

2 FISHING TRIALS

(p.9)

Fishing trials were carried in two periods: (1) In the Vardö area in June 1980 with M/V "Fjellsegga" of Vardö, and (2) on Sveinsgrunnen bank northwest of Senja in February/ March 1981 with M/V "Jörn Steinar" of Gryllefjord. The trials will in the following sections be identified as respectively the Vardö and the Gryllefjord trials. These areas were chosen due to the large differences in size and condition of the fish: The Sveinsgrunnen fishery is chiefly for cod on their spawning migration to and from Lofoten, while Vardö is near the feeding - and growing up areas for both cod and haddock. The fish are therefore considerably smaller in this area.

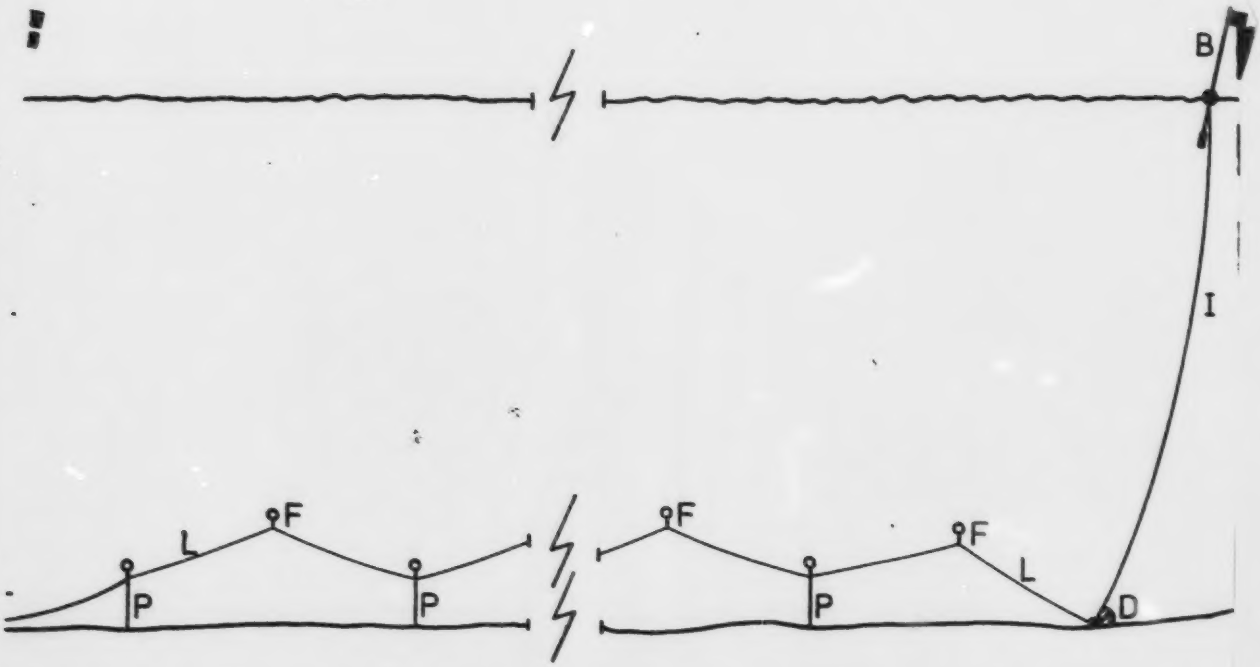
2.1 MATERIALS AND METHODS

2.1.1 Gear, rigging and setting methods.

The longline used was made of monofilament polyamide (gutline). The rigging of this type of longline is shown in figure 2.1.1. The gangion (snood, leader) with hook is fastened to the groundline with a swivel whose purpose is to counteract twisting of the gangion. Stoppers designed to prevent the swivels from sliding are spun into the groundline. The distance between hooks (or swivels) is usually 1.5 - 2.5 metres and the length of the gangions 80 - 90 cm (further specifications are given in Table 2.1.1).

The longline is baited in tubs and for that reason a tub is designated as a longline unit. The length and the number of hooks vary considerably, but in these studies a tub of longline was 400 - 500 metres long and rigged with 200 - 250 hooks. The tubs are set in long strings. A string can consist of a few to up to 100 tubs.

The longlines were set on "poles" (Figure 2.1.2). The name comes from the fact that the longline is lifted from the bottom



Figur 2.1.2. Pålesatt line. L) Line, P) påle, F) fløyt, D) dregg, I) ile, T) tau, B) bøye.

Figure 2.1.2. Longline set with "poles" ("påler"). L) line , P) "pole", F) float, D) anchor, I) buoyline, T) rope, B) buoy (high flier)

with so-called "poles" ("påler") and a floatation device. (p.10) A "pole" consists of a brick and a float connected by a thin rope. Net rings with a buoyancy of ca 475 grams were used both in "poles" and for buoyancy. The poles and the floats (rings) were fastened alternately to the groundline every 50 metres. A buoyline was attached at each end of the line and after every third tub.

The setting method was somewhat different in the two trial periods. In the Vardö trials the groundline was fastened directly to the anchors as shown to the right in Figure 2.1.2. However, in the Gryllefjord trials about 100 metres of rope was inserted between the end buoyline and the groundline as shown to the left in figure 2.1.2, and in the groundlines used after every third tub, the groundline was fastened to the buoyline a few metres above the anchor. This setting method resulted in fewer tangles and at the same time, no parts of the groundline were in contact with the bottom.

In the water the groundline will take on a shape approximately as shown in Fig. 2.1.2, with the "pole" fasteners (brick and rope) as the lowest points of the line and the floats (rings) as the highest. HUSE (1979a) studied the profile of pole set longlines with the help of a diver. He found that the line was approximately linear between the pole and the float, and based on calculations of the specific gravity of mackerel in the sea, he concluded that the bait size would have little influence on the profile of the longline. Otherwise the height differential between pole and float will likely depend on setting speed, depth, currents, size of anchor and the buoyancy of the floats.

2.1.2 Fishing operations.

The fishing trials in the Vardö area were carried out with a 60 foot vessel with a six man crew. The vessel was chartered for our exclusive use and the crew came from FTFI. This gave us much more freedom with respect to the actual implementation of the trials.

The longlines were baited ashore and set in the slope just off Vardö. The depth was 130 - 200 metres and the soak time (p.11) varied from 15 to 20 hours in the middle of the week, while it was 3 days on weekends and holidays. The weather conditions were very good and we only had one day ashore due to strong wind.

In the Gryllefjord trials we used a 45 foot vessel with two men onboard and four baiters ashore. The vessel was only partly chartered for the trials. We were therefore dependent on using the vessels own fishing gear which led to the experimental setup being somewhat different than those in the Vardö trials (Section 2.2.4). The regular gear and the experimental gear were set in two parallel lines with 9 tubs in each. The longline was set on flat bottom at about 80 metres depth. The soak time varied somewhat due to unstable weather conditions; for the experimental line 1 - 4 days and for the regular gear 2 - 6 days.

Table 2.1.1 lists the gear and fishing methods used in the trials. In addition, there is also a summary of the regular fishing operations in the Gryllefjord trials when some data were also collected for this type of fishing gear.

Table 2.1.1. Summary of gear and fishing operations.

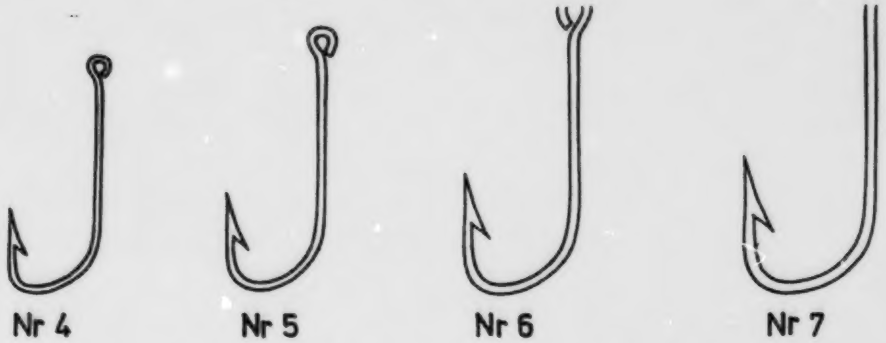
	Vardö trials	Gryllefjord trials	
	Fishing trials	Fishing trials	Regular fishing
Experimental area	Vardö	Sveinsgrunnen Bank	
Fishing Depth (m)	130 - 200	80	
Type of longline	Monofilament polyamide	Monofilament polyamide	
Groundline,dia(mm)	2.0 (no.200)	1.8 (no. 180)	
Gangion,dia.(mm)	0.7 (no.070)	0.8 (no. 080)	
Gangion length (cm)	80	80	
Setting method	"Pole" (float)	"Pole" (float)	
Pole length (m)	10 - 20	2 - 8	
Floatation in poles and floats	Gillnet ring	Gillnet ring	
Buoyancy of rings (g)	475	475	
Distance between pole floats (m)	50	50	
Hook spacing (cm)	200	250	200
No.of hooks per tub	200	200	250
Type of bait	Mackerel	Mackerel	Squid

2.1.3 Hook - and bait sizes.

Figure 2.1.3 shows the hooks tested in regular size. All are of the type Mustad - Norway (quality 7269). In both experimental fishing areas hook no.6 is standard, i.e. the hook most used. Fig. 2.1.4 shows the dimensions measured and the measurements are presented in Table 2.1.2. Ten hooks of each size were measured. The standard deviations are not given due to small variations in the measurements.

Commercial fishermen in the areas studied use chiefly mackerel and squid as bait. However, only mackerel was used in our studies. Various methods of cutting the baits were tested,for example according to certain length and width measurements. Due to the large variation in the size of the bait mackerel and the large number of baits it was necessary to cut each day, the only practical alternative possible was to cut them according to weight. In practice this was done by splitting the mackerel along the backbone in the sagittal plane, followed by removal of the head, tail and gut content. For each bait size an upper and lower weight limit was set , and if there was any doubt about the size of a bait, it was weighed.

The weight limits for the various bait sizes are given in Table 2.1.3. The length and weight measurements of the baits are also included (see Fig. 2.1.5). A total of 50 baits of each size were measured in both trial periods. However, the length dimensions of the baits varied considerably in the trials due to large variations in the bait mackerel. The measurements presented must therefore not be taken as absolute, but as an approximate description of the size. The weight of the baits were, however, continually controlled.



Figur 2.1.3. Forsøkskrokene i naturlig størrelse. Mustad-Norway (kval.7269).

Fig. 2.1.3. Experimental hooks in actual size. Mustad-Norway (qual.7269).

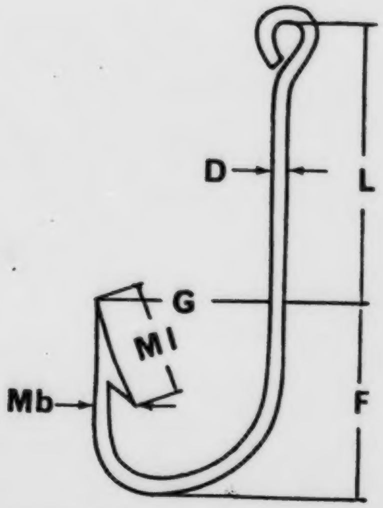


Figure 2.1.4. Hook dimensions measured. L) shank (leg), F) front, G) gap, D) wire diameter, Ml) barb length, Mb) barb width.

Table 2.1.2 Hook dimensions. All measurements are in mm.

Hook No.	Shaft	Front	Gap	Wire	Barb	
	(L)	(F)	(G)	(D)	(Ml)	(Mb)
4	22.5	12.9	12.3	1.25	7.6	2.4
5	23.6	14.4	13.4	1.4	7.8	2.7
6	26.5	16.7	16.0	1.6	9.1	3.8
7	29.2	20.5	17.7	1.8	11.5	3.8

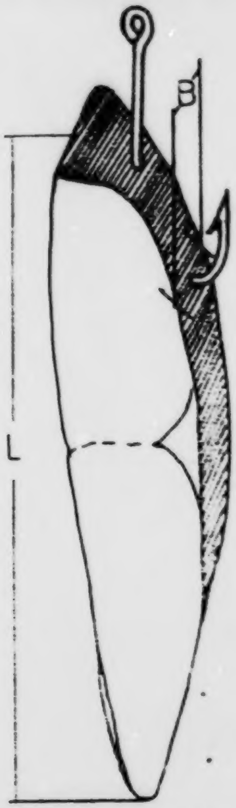


Figure 2.1.5 Thirty gram mackerel bait and hook no.6 in actual size. B) Width, L) Length

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Table 2.1.3 Bait dimensions. Weight limits for the various bait sizes. Widths and lengths are indicated with mean value and upper and lower limits.

	Bait	Weight limits(g)		Widths (mm)			Lengths (mm)		
	(g)	Lower	Upper	Mean	Lower	Upper	Mean	Lower	Upper
Vardö	10	8	12	20	17	25	38	32	43
	20	17	23	18	15	25	69	58	80
	30	25	35	23	18	30	86	70	105
Gryllefjord	10	8	12	18	18	18	44	41	47
	20	15	25	18	18	18	69	60	82
	40	33	47	18	18	18	120	100	149

From the table it can be seen that the dimensions of bait with corresponding weights were not completely alike in the two periods. This is associated with the bait cutting methods used. In the Vardö trials the baits were cut by hand, while in Gryllefjord a bait cutting machine with a fixed distance (18 mm) between the knives were used.

2.1.4 Experimental setup.

In the Vardö trials, bait sizes of 10, 20 and 30 grams and hook sizes nos. 4, 5, 6 and 7 were tried. The different hook sizes were compared with hook no. 6 (the standard hook) in hook vs hook trials, i.e. that the standard hook and a test hook were used in alternate positions along the longline. To study the effect of varying bait sizes, a hook comparisons were carried out with both 10, 20 and 30 gram baits. In practice each tub was divided into three cells with 50 hooks in each (25 of hook no. 6 and 25 of one of the other hooks), and each cell baited with a different size of bait. Between each cell 16 - 17 hooks were cut off so that the distance between the cells was 34 - 36 metres. This was done in order to reduce any "neighbour" effect between the cells, as for example that large baits have a better ability to attract (p.13) fish that can be transferred to small baits. The order of the baits was the same in all the tubs in a setting, so that in addition to the hook comparisons there was also a paired comparison of the bait sizes: cell 1 vs cell 2, cell 2 vs cell 3, cell 3 vs cell 1 in the next tub etc. The bait order was changed from setting to setting so that the position of a bait in a tub would not influence the results. To be able to keep the hooks separate during hauling, about 10 cm of the gangion ends were dyed with Dylon textile dyes. The gangions of hook no. 6 were dyed green , while the others were dyed red. In the light of there being little difference in the contrast of the colours, and because the dyeing method did not materially affect the transparent properties of the polyamide, it is considered unlikely that the dyeing had any effect on the results.

Since it was only the hook sizes that differentiated the different experimental series, they will be labelled according to the hooks: For example, "Trial 65" would have tested both hook no. 5 and no. 6 and the three bait sizes.

In addition to the above mentioned experiments, hook vs hook comparisons of 10 and 20 g baits were done. The two bait sizes were baited in every second position along a longline that was only equipped with hook no.6. In this experimental series the gangion ends were also marked with Dylon colours: Gangions with 10 g baits were dyed red while the others were dyed green.

In the Gryllefjord area 40 g baits and hook no.6 are standard. It was therefore decided to test 40 g baits instead of 30 g baits. Furthermore, hook no.4 was not tested since it was assumed it would be too small for the large fish in this area. The experimental parameters in the Gryllefjord trials were therefore 10, 20 and 40 g baits and hooks nos. 5, 6 and 7. Hook no.6 was used as the comparison hook also in these trials. The experimental setup was essentially the same as in the Vardö trials. However, the longline was set up with 200 hooks per tub and 2.5 metres distance between hooks against respectively 200 hooks and 2 metres in Vardö. For that reason it was decided to use cells with 60 hooks and a distance between hooks of 27 - 28 metres corresponding to 10 cut off hooks.

Table 2.1.4 gives a summary of the various experimental fishing trials from the two periods.

Table 2.1.4. Summary of trials

	The Vardö trials	The Gryllefjord trials
Period	2/6 - 4/7 1980	9/2 - 13/3 1981
Test hook	Nos. 4, 5, 6, 7	Nos. 5, 6, 7
Standard hook in area	No. 6	No. 6
Experimental set-up, hook trials	Hook-vs-hook comparison w/no.6	Hook-vs-hook comparison w/no.6.
Bait type	Mackerel	Mackerel
Test bait (gram)	10, 20, 30	10, 20, 30
Standard bait in area	20	40
Experimental set-up, bait trials	Cell-vs-cell bait comparison	Cell-vs-cell bait comparison
Cell size	50 hooks	60 hooks
Distance between cells (m)	34 - 36	27 - 28

2.1.5 Registration codes.

The data for each hook along the line was recorded during hauling. If there were fish on the hook, the species and the hooking point in the fish was recorded. The hooking points were divided into three groups: "swallowed", "mouth hooked" and "body hooked". All fish hooked so that the hook was not visible with the mouth closed were placed in the category swallowed. In most cases of swallowed the hook was fastened in the back of the mouth cavity and in the neighbourhood of the throat (pharynx), but occasionally the fish had swallowed the hook completely into the stomach. In all cases where further studies were made of the hooking point, fish that had swallowed the hook into the stomach were dead, while by far most of other fish were alive, even after 6 days soak time.

When the hook was fastened in the mouth of the fish so that it was visible it was placed in the category mouth hooked. In most cases the hook was fastened in one the corners of the mouth, while a few were hooked in the lips or in the hard tissue just behind the lips. In both trials mouth hooked fish was by far the largest category. Fish hooked outside the mouth, for example in the eye, were placed in the category body hooked.

When there were no fish on the hook, the bait status was registered in somewhat different categories in the two trial periods. In the Vardö trials the status of the hooks was divided into three: "whole bait", "half bait" and "blank hook". "Whole bait" was used to designate bait that was unchanged from the time it was set, while a "blank hook" represented a hook with insignificant bait remnants or was completely free of bait. Everything between these two extremes was placed in the group "half bait".

On the basis of the experiences in Vardö, the hook status designations were changed somewhat in the Gryllefjord trials. The category "whole bait" was used in the same way, while "blank hook" was used to designate a hook completely free of bait. The baits between these extremes were placed in two groups: "half bait" and "bait remnants". "Bait remnants" was used as designation for bait of ca 3 g down towards 0 g. Often there were only skin remnants left of the bait. "Half bait" comprised everything between this category and "whole bait".

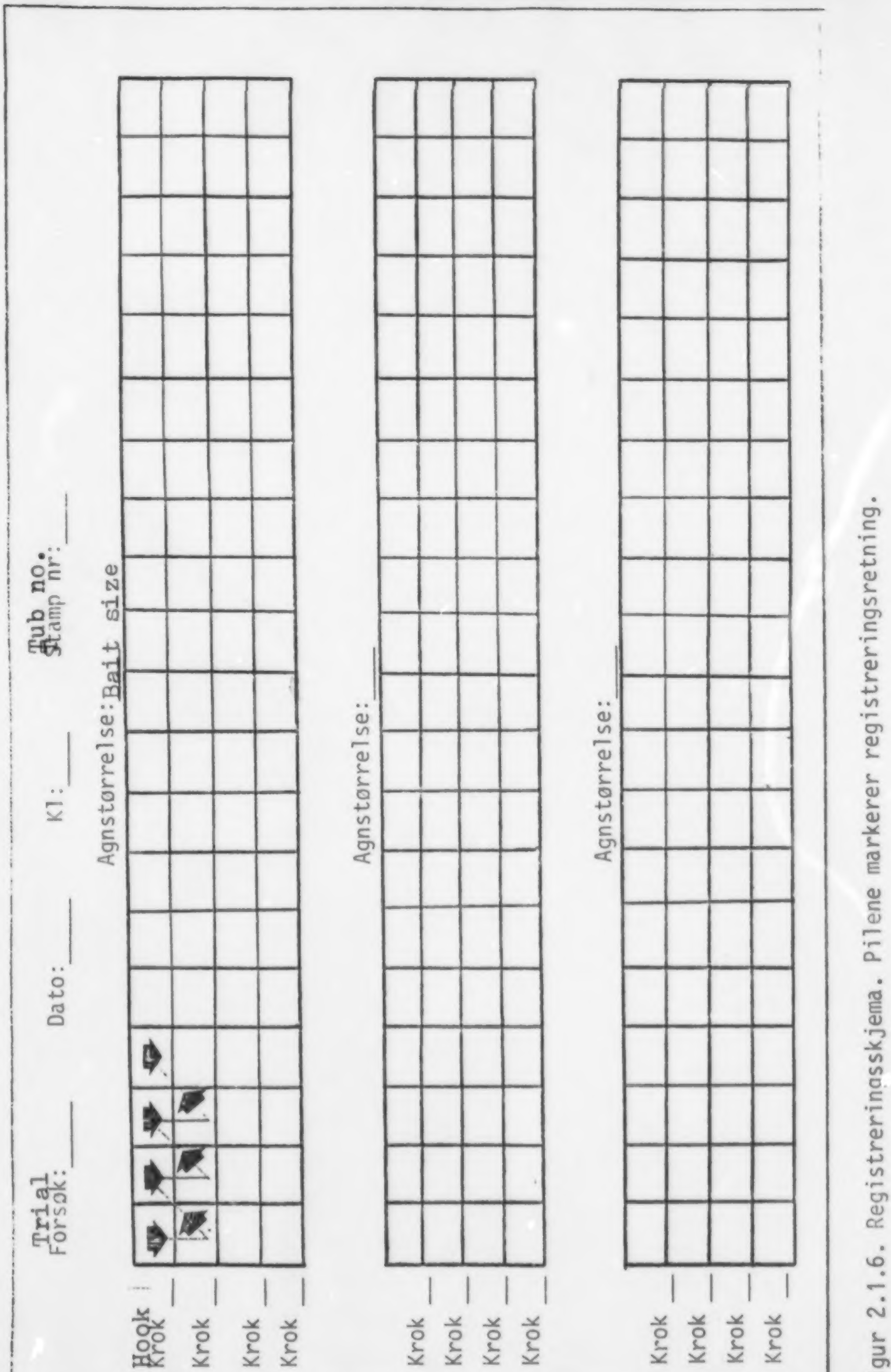
Hooks that were lost or included in tangles were not registered.

2.1.6 Registration. Experiences with different recording methods.

During hauling the observer was sitting on the railing in front of the line coiler and noted the hook status continuously on a form. The form, which is shown in Fig. 2.1.6, is divided into three main columns; one for each cell. The two hook types were recorded in separate rows as shown in the figure. That way the number of codes that had to be registered was reduced to a minimum. In poor weather the forms used had been copied on plastic film (drawing foil). The advantage of these forms is that they can stand water. If they were soiled with fish blood, guts etc., they can even be washed. This made it possible for the same person measuring the fish to also write down the lengths. The hook codes were later entered into the FTFI computer in Bergen.

This recording method is very simple and can be used at all hauling speeds. The greatest disadvantage of the method is that it is difficult to follow developments of the trials due to the large volumes of data being gathered in longline studies.

Registration with the help of audio tape was also tried.(p.16) The method was earlier described by HUSE (1979a). The data are read into a small tape player via a throat microphone. The tape player is started and stopped with the help of a remote control which could, for example, be located in a glove. The data are later transferred to forms, or they can be entered directly into a computer. The advantage of this method is that the observer has



Trial
Forsøk: ___ Dato: ___ Kl: ___ Tub no.
Stamp nr: ___

Agnstørrelse: Bait size

Hook
Krok

Krok

Krok

Krok

Agnstørrelse: ___

Krok

Krok

Krok

Krok

Agnstørrelse: ___

Krok

Krok

Krok

Krok

Figur 2.1.6. Registreringsskjema. Pilene markerer registreringsretning.

Fig. 2.1.6 Registration form for recording data. Arrows mark the direction of registration.

great mobility. Furthermore it can be used at all hauling speeds. However, the method is very labour intensive due to the long time it takes to copy the data (close to three hours for 12 tubs). This makes it even more difficult to keep track of the trials than with the foregoing method.

Attempts were also made to directly enter the hook codes at sea and transfer them to Bergen via telephone. A portable mini terminal of the brand Micronic 445 was used for this purpose and a Texas Silent 700 was used to process the data. The transfer rate for both terminals are 300 baud. Earlier some successful experiments were also carried out to transfer data via an VHF sender (Svein Floen, personal communication). It is then a condition that there is 220 volt current available on the vessel.

Entering the hook codes directly is a considerably more labour saving registration method than the two others. The method also makes it possible to have good control of the trials to prevent that they are concluded too early or prolonged unnecessarily. However, it is assumed that there is an opportunity to transfer the data to a computer and that the programs to process the data are set up and ready to go (the latter is the reason for the fact that direct entering was not used to any large extent in these trials). The greatest disadvantage of the method is that the actual punching in of the data is relatively slow. When the hauling speed is high, it is difficult to register more than two numbers per hook. This means that the method is difficult to use in connection with experimental methodology based on hook - vs - hook (p.17) comparison. It will then usually be necessary to enter three numbers per hook: One number for type of hook, one for fish, if any, and one for the location of the hook fastening point.

2.1.7 Catch data.

Definitions:

Catch - number of fish caught

Cell - longline unit of respectively 50 and 60 hooks in the Vardö and Gryllefjord trials.

Hooks used - number of registered hooks. Hooks caught in tangles or lost hooks were not registered.

Catch rate - ratio between catch and number of hooks used.

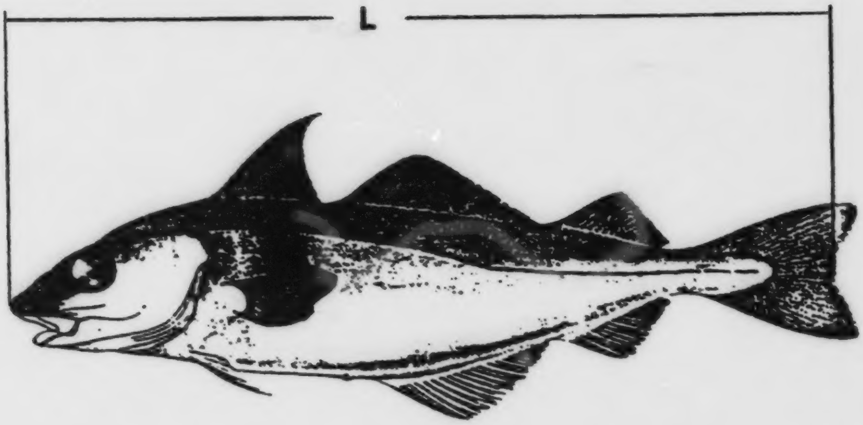
Hooking probability - the probability of a fish being hooked by attacking the bait.

Relative catch differential - the percentage difference between the catch of for example two hook sizes. The catch differential is always calculated on the basis of the smaller catch so that it corresponds to the increase in catch.

Tangles often occur during the setting of the longline, either due to careless baiting or due to the current pulling the line together. So that larger tangles would not influence the results, cells were rejected where more than 20 percent of the hooks were tangled. For the bait comparisons that were carried out by paired comparisons of cells, the pairs were rejected. In addition, cells without fish were rejected in the hook comparisons, while in the bait comparisons pairs without fish were rejected.

2.1.8 Biological data.

The lengths of most of the fish were measured. However, when catch rates were very high, only fish on every second cell were measured. If there were doubts as to which hook the fish were caught, they were not included in the length data. This applied especially in poor weather due to fish falling off the line before being landed.



Figur 2.1.7. L) Lengden som blei målt på fisken. Fisken er kopiert fra verket Havet og våre fisker (ROLLEFSEN _et al_. 1960)

Figure 2.1.7. L) Fish length measured. The fish is copied from the book Havet og Våre Fisker (ROLLEFSEN _et al_, 1960)

The length of the fish was measured as shown in Fig. 2.1.7. The length was rounded off downwards to the nearest cm. This measuring method is not commonly used in that it is usual to measure the overall length of cod and haddock. Since the method was used at the start of the trials, it was kept throughout both trials. For cod there is practically no difference between the two measuring methods, while for haddock it has some effect since the tail fin is relatively deeply indented as shown in Fig. 2.1.7.

All measured fish were included in the length results for the various parameters; also fish that were caught in cells that were not included in the catch data.

On several occasions randomly chosen fish were subjected to more thorough biological studies. The fish were then measured, weighed, the liver was weighed, the hooking point studied more closely and the stomach examined with respect to fullness and contents. The degree of fullness were classified according to the following criteria: (1) empty, (2) food remnants, (3) half full, (4) full, (5) spilling over and (6) inside out (out of the mouth).

The condition factor of the fish was calculated on the basis of the following formula:

$$k = 10^5.W/L^3,$$

where W is weight in kg and L is length in cm.

2.1.9 Selectivity (p.19)

Gear selectivity, as the concept is used here, is defined by LAGLER (1978), while HAMLEY (1975) and POPE et al (1975) has given more thorough descriptions of the various aspects of selectivity. Therefore, only a brief description of the concepts used in the thesis will be given:

Selectivity - the relative catching ability of a hook or a bait for varying fish sizes. Selectivity and length selection are used synonymously.

Selection curve - curve that describes the selectivity.

Effectivity - the area under the selection curve.

Catch curve - curve showing the size of the catch in length intervals. The area under the curve is equal to the catch.

2.1.10 Statistics.

All statistical tests are applied two - sidedly and they are based on the zero hypothesis that the samples in question belong to the same distribution. When a difference is designated as significant or statistically significant, it means that the possibility that it would occur randomly is less or equal to 5 percent.

For statistical testing of the catch results in the hook studies the "sign"(?)test ("fortegnstesten") (LEHMANN 1975) was used which is a paired test where the output is 0 and 1. The pairs in question consisted of adjacent hooks that either had a fish on (1) or was without a fish (0). In case the difference between a pair was zero, in practice a pair without fish or a pair with fish on both hooks, it was not included in the test.Since the species were handled separately, there was a problem when there was a catch of different species in a pair. If such pairs are rejected, much information is lost. Hooks with species of no interest were (p.20) therefore considered to be without fish. The effect this will have on the test will depend on the numbers of such pairs and if there is a large difference in the catching power of the comparative hooks with respect to species of interest. Possible effects as a result of this will be evaluated.

A t-test for paired comparisons (ZAIR 1974) was used to evaluate the catch data from the bait trials. The method involves measuring the differences in the pairs followed by a t-test on the mean value in the differential distribution. For simplicity, the test results are discussed as if it is the total catch that has been tested and not the average catch per cell. The t-test assumes that the sample has normal distribution, but it is quite robust for deviations from this requirement (ZAR 1974). In the case of skewed distributions, COCHRAN's (1977) rule of thumb for estimating confidence intervals can be used: Distributions with a positive skewness must have a sample size which is at least 25 times the square of the skewness coefficient. To study if this requirement has been met, the skewness coefficient in the differential distribution is calculated, and all cases where the skewness was too great has been noted.

For statistical analysis of the length results, non-parametric tests were chosen. This is associated with the fact that some samples have quite long tails and for that reason would not meet the requirements for normal distribution. According to LEHMANN (1975), the Mann-Whitney test (non-parametric) is considerably more effective than a two-sample t-test if there are long tails on the distributions (effectiveness will mean power to reject the zero hypothesis if it is false). If the samples are normally distributed, the loss of effectiveness by using the Mann-Whitney test is about 5 percent, while at smaller deviations from normal distribution, there are only small differences in effectiveness between the tests. Even if some distributions have basis for utilizing parametric tests, considerations to uniform processing were given priority.

The following tests were used: Mann - Whitney (p.21) (ZAR 1974) for testing of two and two length distributions, and Kruskal - Wallis (ZAR 1974) for testing of three or more. If the Kruskal - Wallis test rejects the zero hypothesis, ie that at least one of the "mean lengths" is different from the others, there is basis for further testing with Mann - Whitney to determine which are different. The reason for having to go through a multi-sample test is that the danger of erroneous rejection of the zero hypothesis increases considerably with the number of samples (ZAR 1974). However, all results of the Mann - Whitney test are presented, but in case the basis for the test is not there, a special note has been made to point this out.

Some of the samples in this study consist of fractions between 0 and 1. According to statistical theory such samples are usually binomially distributed (ZAR 1974). This means that parametric tests cannot be used on them without reservation. However, the problem can be solved by converting the data with the help of an arcus - sinus transformation (ZAR 1974). With all such transformations, and otherwise with the use of parametric tests, a study was made to see if the samples had an approximately normal distribution through visual evaluation of the normal distribution plot in addition to study of the magnitude of skewness and kurtosis.

In all cases where data from different experiments have been combined, the statistical basis has been studied first.

In addition to the statistical tests mentioned above, the following tests and analyses have been used:

- Two - sample Kolmogorov - Smirnov test (SIEGEL 1956).

- Wilcoxon's test for paired comparisons (LEHMANN 1975).

- The binomial test (ZAR 1974).

- Various Chi - square heterogeneity tests (ZAR 1974) (p.22)

- Linear regression analysis (ZAR 1974)

- T - tests to see if the regression coefficient differs from zero (ZAR 1974).

- Linear correlation analysis (ZAR 1974)

- Partial, linear correlation analysis (DIXON & BROWN 1979)
- T - tests to see if the correlation coefficient differs from zero (ZAR 1974).
- T - tests to see if two correlation coefficients are different (ZAR 1974).
- Tests to see if three or more correlation coefficients are different (ZAR 1974).

2.1.11 Data processing.

All data that this thesis is based on have been entered into the FTFI computer in Bergen, a Hewlett-Packard 1000. For most of the summations, calculations and statistical tests FORTRAN programs have been developed,in total a little over 100 programs. The accuracy of the statistical tests has been checked with the statistics package BMDP (Biomedical computer programs, DIXON & BROWN 1979) on the EDP installation at the University in Bergen, UNIVAC 1100/82.

2.2 THE HOOK COMPARISONS - RESULTS AND DISCUSSION. (p.23)

In addition to the hook comparisons, this chapter also includes a study carried out in the laboratory (Section 2.2.1). The reason for presenting it here is that it is illuminating for the hooking process. The results of the fishing trials are otherwise presented in the sequence they were collected, and cod and haddock are discussed separately. For practical reasons it has not been possible to include all the data that the different calculations and analyses are based on. The raw data are available from Fiskeriteknologisk Forskningsinstitutt, Bergen.

2.2.1 Preliminary studies of the penetrating force of the hook.

The objective of this study was with the help of a simple measuring method to study if the penetrating force of a hook depends on the size of the hook (penetrating force is defined as the force necessary to force a hook deep enough into the fish flesh for the barb to engage). In addition it was also of interest to find out if the size of the fish was of importance. The objective was not to describe the absolute relations between penetrating force and hook - and fish size since a considerable volume of experiments and advanced measuring instruments unavailable to us would be needed.

Two groups of cod totalling 7 live fish were purchased. Group I consisted of three fish of 36, 37 and 38 cm, and group II of four fish of 49, 52, 52 and 53 cm. The fish were killed about one hour before starting the experiments. The measurements were carried out by placing the hooks in various localities in the mouth, and the leaders (gangions) slowly and as evenly as possible tightened by hand. The gangions were placed approximately at right angles to the surface the hooks were tested on. The force was measured with the help of a spring scale with a measuring accuracy of (p.24) 0.10 N (Newton). Twelve measurements were made on each fish; six in the skin fold just above the corner of the mouth and six in the skin fold just below. Hook no. 4 was tested on one side of the mouth (three measurements above and three below) and hook no. 7 on the other side.

The hook penetrated the fish skin in two stages. The sharp tip first penetrated the skin and the force then had to be increased somewhat before the barb penetrated with a jerk. It was not possible to measure the penetrating force with this crude measuring method. It was still clear that the force for hook no.4 was considerably less than for hook no.7 in that hook no.4 penetrated the skin as soon as the tightening force was applied, while hook no.7 often slid on the skin. With both hooks the strongest force was needed to made the barb penetrate.

The results of the measurements are presented in Table 2.2.1. the penetrating force for hook no.7 was approximately twice that of hook no.4 ($p<0.001$, the Mann-Whitney test) regardless of the size of the fish and test surface (upper of lower skin fold). The penetrating force was also approximately twice as high for the large fish as for the little ($p<0.001$).

On the basis on these results it seems to be clear that the penetrating force increases considerably with the size of both fish and hook, and since the largest force was needed to force the barb through the fish skin, it is probably the dimensions of the barb that is decisive for the magnitude of the penetrating force.

2.2.2 Cod - The Vardö trials

In the duration of these studies the catch varied somewhat. In the first part of the period, at the time when Trial 65 (ie comparison of hooks no.5 and 6 with 10, 20 and 30 gram baits) and Trial 67 was carried out, the catches were somewhat uneven, but with mostly good catches of cod. Catches dropped considerably during Trial 64, and towards the end of this period there were only sporadic cod catches. In addition to cod and haddock, there were also occasional catches of cusk, redfish, Atlantic wolffish, spotted wolffish and dogfish, but catches of these were so small that they will not be further evaluated.

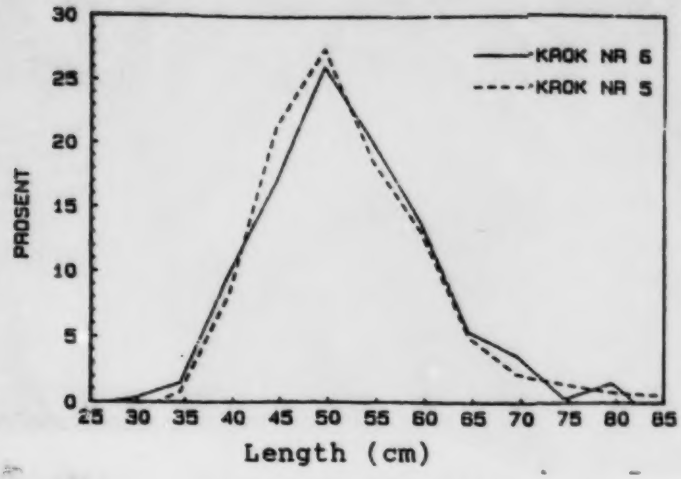
Table 2.2.1 Penetrating force of the hook measured in N (newton) on smaller (Group I) and larger cod (Group II). The measurements are given with mean value +/- 95% confidence intervals. The values in Group I are based on 9 measurements, against 12 in Group II.

Hook (no)	Under corner of mouth		Above corner of mouth	
	Group I	Group II	Group I	Group II
4	1.56 +/-0.22	2.67 +/-0.39	0.63 +/-0.14	1.20 +/-0.16
7	2.40 +/-0.38	4.58 +/-0.92	1.28 +/-0.30	2.55 +/-0.49

Comparison of hooks nos. 5 and 6.

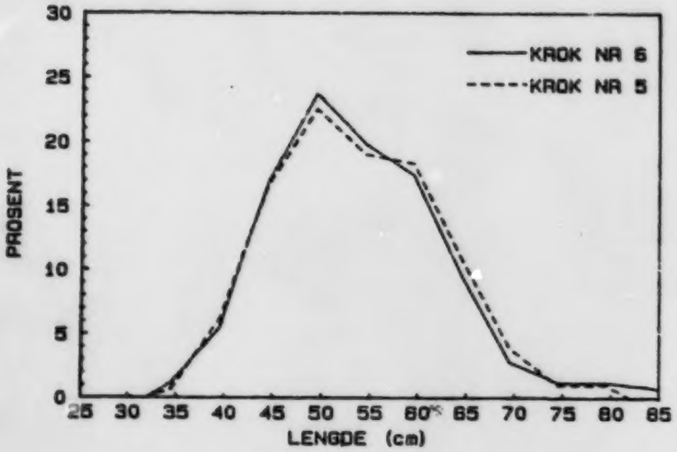
The results of these comparisons are presented below. Figure 2.2.1 shows the catch - and length results and also the relative length distributions for hooks nos. 5 and 6 with 10 gram baits. From the table it can be seen that hook no. 6 caught 314 cod and that this corresponded to a catch rate of 0.29 fish per hook. The corresponding numbers for hook no. 5 was 377 and 0.36. In other words, hook no. 5 gave a catch increase of 20.1 percent. The probability that the observed difference has occurred randomly is calculated to be 0.003 with the help of the "sign"(p.28) test.

The length results are given in the table in the line below the "sign"- test value. The lengths of 333 cod caught on hook no. 6 and 360 on hook no. 5 were measured. The mean lengths were respectively 51.7 and 51.5 cm. The precision in the estimate of the mean length is given with 95% confidence interval, and the



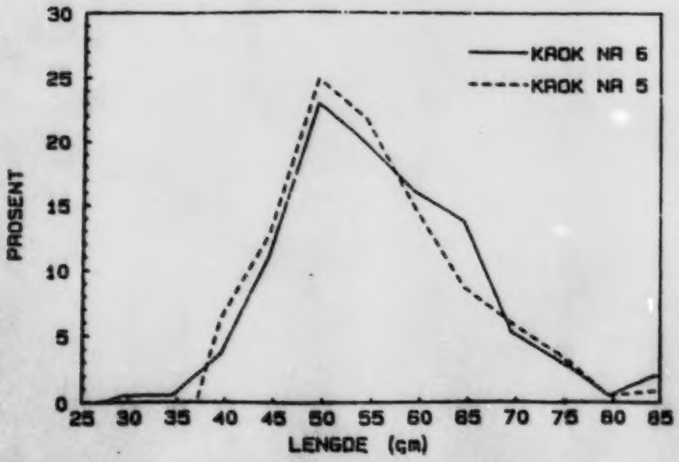
Hook no.	6	5
No. of cod	314	377
Fish per hook	.29	.36
Difference (%)	20.1	
"Sign" Test	0.003	
Nos. measured	333	360
Mean length	51.7	51.5
+/- 95% Confid.	.96	.88
Mann-Whitney	.522	

Figure 2.2.1 Comparison of hooks nos.5 and 6 with 10 g bait. Catch- and length data for cod.



KROK NR	6	5
ANTALL TORSK	239	298
FISK PA KROK	.24	.31
FORSKJELL (%)	24.7	
FORTEGNSTEST	.003	
ANTALL MÅLT	253	306
MIDDELLENGDE	53.3	53.3
+/-95% KONF.	1.08	.86
MANN-WHITNEY	.923	

Figure 2.2.2 Comparison of hooks nos. 5 and 6 with 20 g bait. Catch- and length data for cod.



KROK NR	6	5
ANTALL TORSK	182	225
FISK PA KROK	.18	.23
FORSKJELL (%)	23.7	
FORTEGNSTEST	.016	
ANTALL MÅLT	188	218
MIDDELLENGDE	55.6	54.1
+/-95% KONF.	1.43	1.20
MANN-WHITNEY	.168	

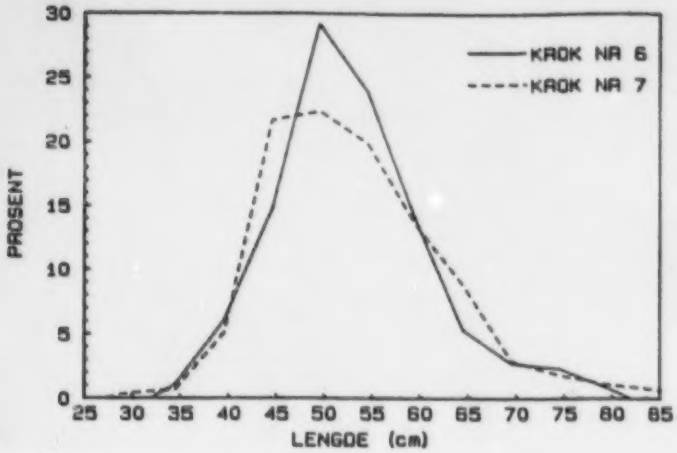
Figure 2.2.3. Comparison of hooks nos. 5 and 6 with 30 g bait. Catch- and length data for cod.

probability of 0.552 that the two hooks caught cod of equal length was calculated using the Mann - Whitney test. The test result together with the length distribution curves show that there was no size differences in the fish caught on the two hooks.

From the table it can be seen that the number of fish measured and the catch results do not agree. This is connected with the way the length measurements were done, and that cells that were rejected in connection with catch data have been included in the length results.

In the comparisons with 20 and 30 gram baits the catch increase in favour of hook no. 5 was approximately as large (p.26) as with 10 gram baits, and in this case there was also no difference in the length of the fish.

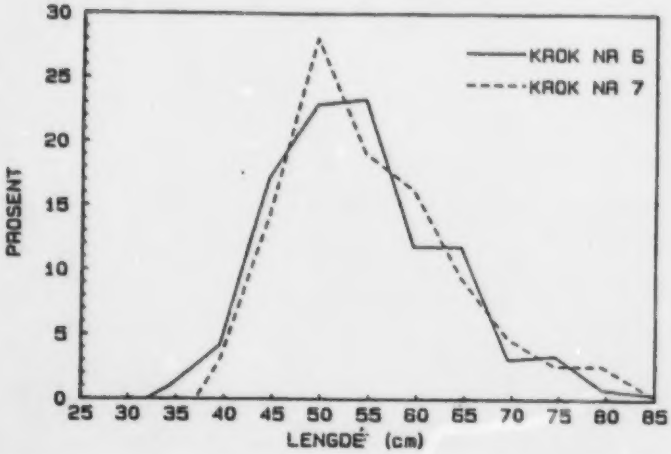
Based on the unambiguous results it seems to be clear that the selective properties of hooks nos. 5 and 6 are approximately the same, but that hook no. 5 is more effective than hook no. 6. However, the bait size does not seem to be of any importance for the relative catch differential between the hooks.



KROK NR	6	7
ANTALL TORSK	270	271
FISK PR KROK	.27	.27
FORSKJELL (%)	.4	
FORTEGNSTEST	.958	
ANTALL MÅLT	284	272
MIDDELLENGDE	52.3	52.1
+/-95% KONF.	.96	1.25
MANN-WHITNEY	.893	

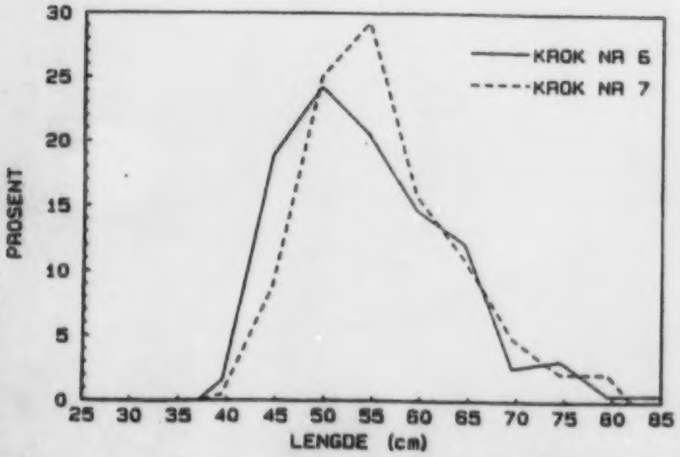
(see p.35)

Figure 2.2.4. Comparison of hooks nos. 6 and 7 with 10 g baits. Catch - and length data for cod.



KROK NR	6	7
ANTALL TORSK	222	198
FISK PR KROK	.24	.22
FORSKJELL (%)	13.2	
FORTEGNSTEST	.131	
ANTALL MÅLT	262	235
MIDDELLENGDE	53.7	54.6
+/-95% KONF.	1.06	1.16
MANN-WHITNEY	.385	

Figure 2.2.5. Comparison of hooks nos. 6 and 7 with 20 g baits. Catch - and length data for cod.



KROK NR	6	7
ANTALL TORSK	192	179
FISK PR KROK	.19	.18
FORSKJELL (%)	7.3	
FORTEGNSTEST	.443	
ANTALL MÅLT	190	184
MIDDELLENGDE	54.4	55.7
+/-95% KONF.	1.29	1.18
MANN-WHITNEY	.058	

Figure 2.2.6. Comparison of hooks nos. 6 and 7 with 40 g bait. Catch and length data for cod.

Comparison of hooks nos. 6 and 7.

The results of the comparisons of hooks nos. 6 and 7 are presented in the figures on the opposite side. There were not significant differences in any of the comparisons either with respect to catch or lengths. The results therefore show that hooks nos. 6 and 7 are approximately equally effective within the length intervals in question and that they also have the same selective properties.

Comparison of hooks nos. 4 and 6.

In the comparison with 10 g baits (Fig.2.2.7), hook no. 4 caught significantly more cod than hook no. 6, which in return caught larger fish. With 20 g baits (Fig. 2.2.8) the catch increase in favour of hook no. 4 was approximately as large as with 10 g baits. However, there were no difference in the mean lengths here. With 30 g baits (Fig. 2.2.9) there were not statistically significant differences either with respect to catch or length, but in this case also there was a somewhat larger catch on hook no. 4.

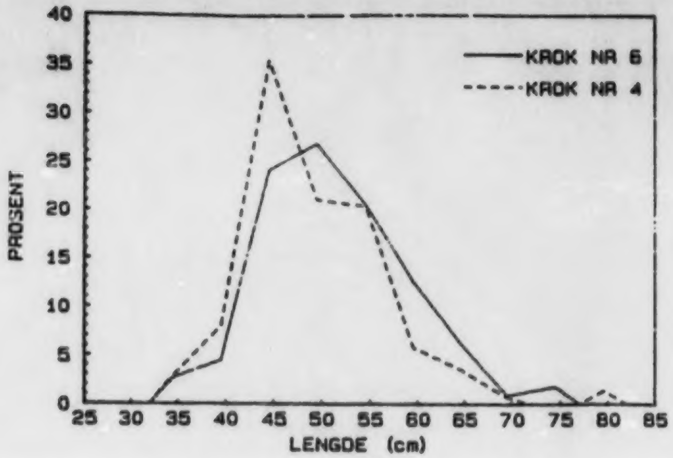
The results of these comparisons therefore show that hook no. 4 is more effective than hook no.6 within the actual length intervals. With 10 gram baits there is a difference in the selective properties of the hooks due to the fact that hook no. 4 is more selective than fish under ca 50 cm. With 20 and 30 g baits it does not appear, however, to be selectivity differences between the hooks.

Briefly summarized, the results from the different experimental series show that there are not substantial differences in the selective properties of hooks nos. 4, 5, 6 and 7. The small differences registered are in all cases due to the largest hook in the comparisons was less effective for fish under a certain length. In no cases were there larger catches of large fish on the largest hook. The results also show that the bait size does not have any influence of importance on the relative differences in effectivity between the hooks. Otherwise it is interesting to note that both hooks nos. 4 and 5 were more effective than hook no. 6 which is standard in the area.

Other species.

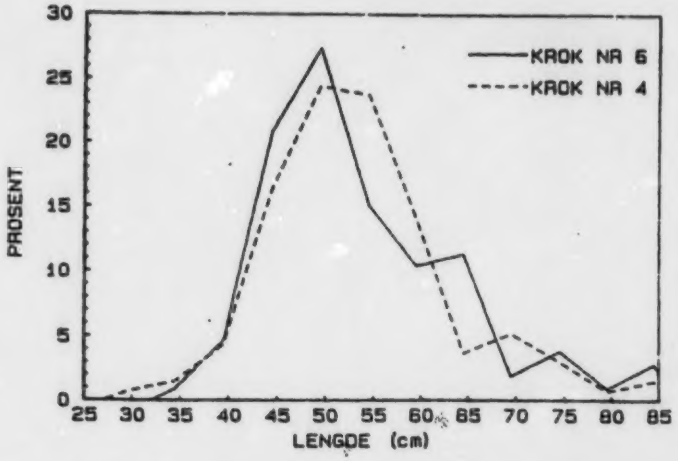
If one of the hooks being compared is more effective than another for non - target species of no interest in these trials (i.e. all species except cod), it can lead to the difference in catch being wrongly estimated, especially if the catch of other species is large. In Table 2.2.2 the number of pairs with cod and other species are presented. In the comparison with 10 gram baits in Trial 65 there were a total of 564 pairs, of which 44 pairs with cod on hook no. 6 and other species on hook no. 5, and 43 pairs with cod on hook no. 5 and other species on hook no. 6. Also in the other comparisons there were approximately the same number of pairs with other species on both hooks. It is therefore not very likely that the non - target species have had any influence of importance on the estimated catch differences.

(See p.35)



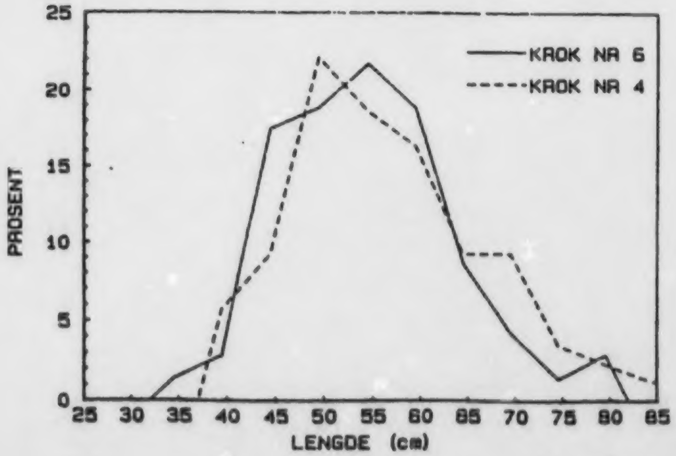
KROK NR	6	4
ANTALL TORSK	94	121
FISK PR KROK	.16	.20
FORSKJELL (%)	28.7	
FORTEGNSTEST	.032	
ANTALL MÅLT	112	138
MIDDELLENGDE	50.9	49.1
+/-95% KONF.	1.43	1.41
MANN-WHITNEY	.019	

Figure 2.2.7. Comparison of hooks nos. 4 and 6 with 10 g baits. Catch - and length data for cod.



KROK NR	6	4
ANTALL TORSK	106	136
FISK PR KROK	.14	.18
FORSKJELL (%)	28.3	
FORTEGNSTEST	.026	
ANTALL MÅLT	106	135
MIDDELLENGDE	53.8	53.6
+/-95% KONF.	1.98	1.71
MANN-WHITNEY	.916	

Figure 2.2.8. Comparison of hooks nos. 4 and 6 with 20 g bait. Catch - and length data for cod.



KROK NR	6	4
ANTALL TORSK	61	73
FISK PR KROK	.08	.10
FORSKJELL (%)	19.7	
FORTEGNSTEST	.266	
ANTALL MÅLT	69	86
MIDDELLENGDE	54.8	56.9
+/-95% KONF.	2.62	2.48
MANN-WHITNEY	.257	

Figure 2.2.9. Comparison of hooks nos 4 and 6 with 30 g baits. Catch - and length data for cod.

Hook fastening point.

During hauling, the point where the hook was fastened was noted. The results of these studies are presented in table 2.2.3. Most of the cod were hooked in the mouth.

Fish that had swallowed the hook represented from 10 to 30 percent of the catch on the different hook/bait combinations. The occurrence of body - hooked cod was only sporadic, and will for that reason not be further evaluated.

For statistical testing of the different catches, for example if the catch of mouth - hooked fish on hooks nos. 5 and 6 was different, the binomial test was used. Expectations were calculated on the basis of registered hooks. To study if the ratio between mouth hooked and swallowed hooks was different on the hooks being compared, a Chi - square contingency table test was used. If all the results in a series pointed the same direction, the material was combined before being subjected to statistical testing.

---Table 2.2.2. Other species. The table shows the total number of pairs with cod in the different comparisons and number of pairs with non - target species on the different hooks.

	10 grams agn	20 grams agn	30 grams agn
Krok nr 6	44	27	17
Krok nr 5	43	30	14
Antall par	564	462	364
Krok nr 6	37	23	15
Krok nr 7	30	20	18
Antall par	452	357	329
Krok nr 6	13	16	4
Krok nr 4	22	19	3
Antall par	187	210	125

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From Table 2.2.3 it can be seen that hook no. 5 in all comparisons caught more cod than hook no. 6 both of mouth - hooked and hook - swallowed fish. In total for all bait sizes the increase in catch was 21.8 percent for mouth - hooked fish ($p<0.001$), and 28.5 percent for fish that had swallowed the hook ($p=0.008$). The ratios of mouth - hooked and hook swallowed fish was ,however, not different for the two hooks ($p=0.681$). The results therefore show that hook no. 5 is better than hook no.6 independent of the hooking point, and that the fastening point in the fish mouth is about the same for both hooks.

There were no differences in the catching power of hooks nos. 6 and 7 with any bait size. An analysis of the contingency tables of mouth - hooked and hook swallowed fish showed that the ratio between the catches on the two hooks were not different either ($p>0.25$). It therefore seems to be obvious that hooks nos. 6 and 7 are approximately just as effective independently of the hook fastening point.

The catch of mouth - hooked cod was in all cases greater on hook no. 4 than no. 6 ($p<0.025$), while there were, however, no statistically demonstrable differences in the catch of fish that had swallowed the hook ($p=0.125$). There was furthermore a significant difference in the ratios of mouth - hooked fish and fish that had swallowed the hook on the two hooks ($p=0.001$). (p.29) It therefore seems to be obvious that hook no. 4 is more effective in catching cod by hooking them in the mouth than no. 6, while the two hooks are about equally effective to catch fish further back in the mouth cavity (swallowed).

Briefly summarized, the results show that both hooks no.5 and 7 had the same hooking points in the fish mouth as hook no.6, while hook no. 4 in contrast caught relatively more mouth-hooked cod.

Table 2.2.3. Hook fastening point - cod.

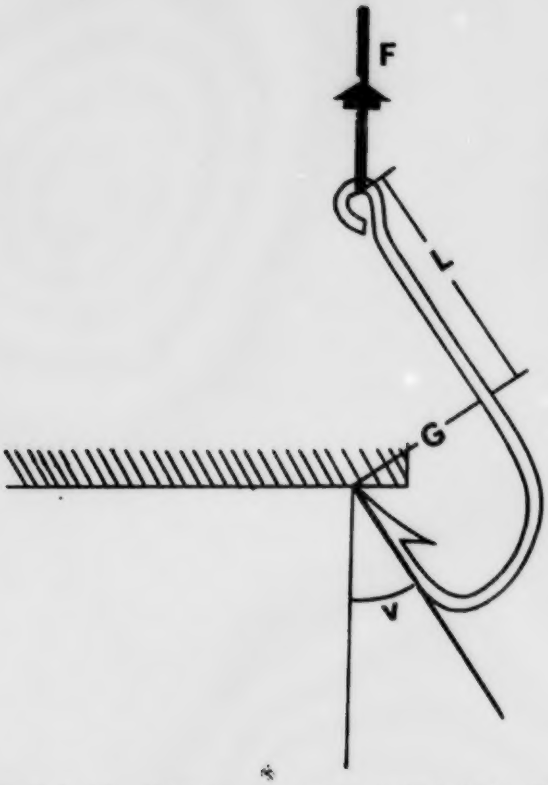
Bait (gram)	Hook no.	Hook fastening point Mouth	Swallowed	Body	Registered hooks.
10	6	233	68	13	1069
	5	280	89	8	1058
20	6	156	75	8	988
	5	203	88	7	975
30	6	134	43	5	999
	5	154	62	9	994
10	6	223	41	6	1018
	7	221	36	14	1017
20	6	170	44	8	917
	7	153	37	6	904
30	6	140	48	4	997
	7	118	54	7	993
10	6	74	15	5	604
	4	105	13	3	602
20	6	72	29	5	751
	4	107	23	6	749
30	6	36	24	1	741
	4	58	14	1	726

Discussion.

Regarding possible reasons for a smaller hook being more effective than a larger hook, three factors stand out: (1) Small hooks have a more favourable angle of attack, (2) have a more advantageous penetration point in the fish mouth, (3) penetrate the fish flesh easier (low penetration force).

(1) The theoretical angle of attack of a hook (Fig. 2.2.10) is dependent on gap and shaft length of the hook (BARANOV 1976).The angle is given by arcus tangent to the ratio between the gap (plus half the wire diameter) and the shaft length. A large angle of attack results in a smaller part of the force in the gangion is decomposed in the direction of the hook point. The force component is given by the cosine of the angle of attack, and for the hooks tested, it was respectively 0.87, 0.86, 0.85 and 0.84 (the values are arranged according to increasing hook numbers), in other words very small differences. It is therefore obvious that the angle of attack does not have any practical influence on the effectiveness. But with a hook type where the point points in the direction of the eye, all force will be exerted in the direction of the hook point, and this factor could then be of great importance.

(2) That one hook has a more advantageous attack point than another, means that the hook for one reason or another (for example due to the size of the gap) more often will hit areas in the fish mouth where it can easily can fasten itself, for example in the lips or the corners of the mouth. The hook fastening studies showed (p.30)
that a considerably larger part of the catch on hook no.4 consisted of mouth - hooked fish than on hook no. 6. There is therefore reason to believe that the two hooks have different hit points. The hit point can therefore be a contributing factor to the higher effectiveness of hook no. 4. This is , however, probably not the only explanation since hook no. 5 gave approximately the same



Figur 2.2.10. Krokens angrepsvinkel (v). F) Forsyn (pila viser kraftretningà), L) legg, G) gap.

Figure 2.2.10. The angle of attack (v) of the hook. F) Gangion (the arrow gives direction of force), L) shaft, G) gap.

increase in catch as hook no. 4 without having a different hooking point than hook no. 6.

(3) Since hooks nos. 5 and 6 had same fastening point in the fish mouth, the penetrating ability emerges as a more likely explanation of the observed differences in effectiveness. Three factors could have an influence on the penetrating ability: (i) the point (the sharpness), (ii) the length of the barb and (iii) the width of the barb (in reality the area of the cross section of the barb which is dependent on both the width of the barb and the wire diameter).

(i) The importance of the point for the effectiveness has been studied by FERNÖ, TILSETH & SOLEMDAL (1977) in connection with behaviour studies of whiting. The tests were done with two sizes of sharp and dull hooks. Different sharpness had no influence on the catching power of the hooks. On the other hand, the small hooks (also the dull versions) caught considerably more whiting than the large hook which clearly indicates that it must be other factors with the hook that are decisive for the catching effectiveness for whiting. In the introductory studies of this thesis, it was observed that the penetrating force was considerably larger than the force needed for the point to penetrate the skin. It is therefore reason to believe that the point is not of great importance for the catch of cod.

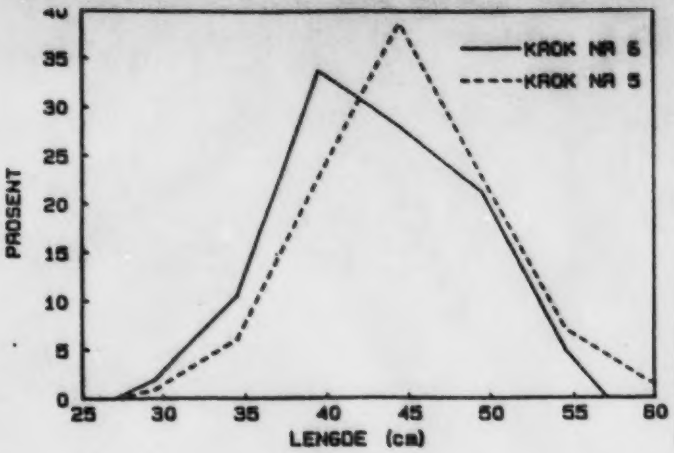
(ii) The length of the barb could be of importance if the hook hits bone. From Table 2.1.2 it can be seen, however, that the greatest difference between barbs was in hooks nos. 6 and 7 which turned out to be about equally effective. It is therefore not very likely that the length of the barb has been of great importance in these trials. (p.31)

(iii) During the introductory study of the penetrating force of the hooks it was observed that the greatest force was needed to force the barb through the fish skin. The difference in penetrating force between hooks nos. 4 and 7 was in addition large (ca 100%). If we compare the various dimensions of the hooks in Table 2.1.2 with the observed differences in effectiveness, an interesting relationship appears. It was found that the width of the barbs in hooks nos 6 and 7 were the same (3.8 mm), while the it is less both on hook no.4 and no. 5 (respectively 2.4 and 2.7 mm). Consequently this gives a reasonable explanation of the fact that there was no difference in effectiveness between hooks nos. 6 and 7, and that both hooks nos. 4 and 5 were more effective than hook no. 6. The width of the barb therefore seems to be of the greatest importance for the observed differences in effectiveness between the hooks.

That there were no differences in selectivity between the hooks could have been a serious objection against the hypothesis that it was the penetrating ability of the hook that was decisive for the differences in effectiveness. OSHIMA (1953) found that the force the fish Sebasticus marmoratus attacked the hook with was approximately proportional with the body weight. There is reason to believe that this also applies to other species. In that a larger force is needed for a larger hook to penetrate the fish flesh than a smaller hook, it should be expected that it would result in selectivity differences in that small fish would not be hooked on large hooks. When this is not the case, it was probably due to the fact that the penetrating force, which in the preliminary study was shown to be dependent on the size of the fish, approximately balance the increased force with which larger fish attack the hook.

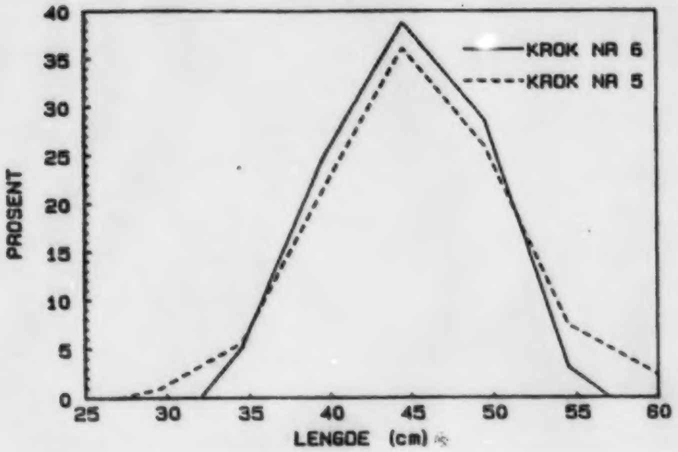
2.2.3 Haddock - The Vardö trials. (p.32)

The catches of haddock were quite irregular during Trials 65 and 67. Often there were only two to three fish per cell, but there were also cases where the catch rate was well over 0.5 fish per hook. While Trial 64 was on, catches of haddock increased considerably, and towards the period haddock were quite plentiful. The results are otherwise from the same experimental series as the cod results. However, cod and haddock did not mix on the longlines to any great extent.



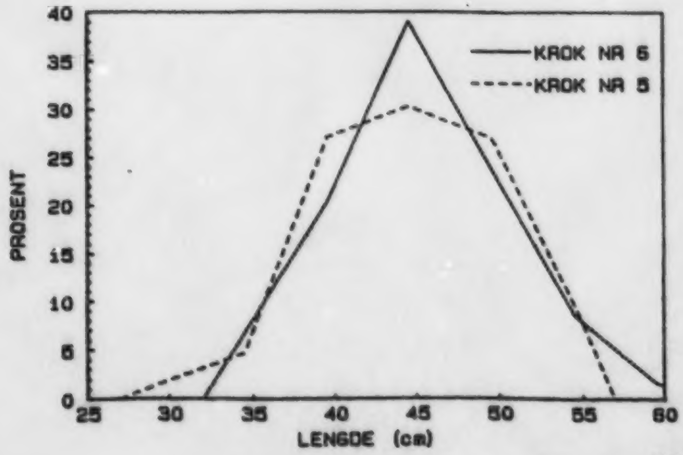
Hook no.	6	5
No of haddock	144	180
Fish per Hook	.16	.21
Difference (%)	25.0	
"Sign"test	.017	
Numbers Measured	104	114
Mean length	42.9	44.4
+/-85%confidence	1.09	.88
Mann-Whitney	.048	

Figure 2.2.11. Comparison of hooks nos. 5 and 6 with 10 g baits. Catch and length data for haddock.



KROK NR	6	5
ANTALL HYSER	119	141
FISK PR KROK	.16	.20
FORSKJELL (%)	18.5	
FORTEGNSTEST	.105	
ANTALL MÅLT	88	108
MIDDELLENGDE	44.3	44.8
+/-85% KONF.	.88	1.05
MANN-WHITNEY	.579	

Figure 2.2.12. Comparison of hooks nos.5 and 6 with 20 g baits. Catch and length data for haddock.



KROK NR	6	5
ANTALL HYSER	71	71
FISK PR KROK	.11	.11
FORSKJELL (%)	0.0	
FORTEGNSTEST	.999	
ANTALL MÅLT	59	63
MIDDELLENGDE	44.5	44.6
+/-85% KONF.	1.40	1.38
MANN-WHITNEY	.896	

Figure 2.2.13. Comparison of hooks nos.5 and 6 with 30 g baits. Catch and length data for haddock.

Comparison of hooks nos. 5 and 6.

The results of these comparisons are presented in the figures on the previous page. In the comparison with 10 g baits there was a significant higher catch on hook no. 5 of 25 percent. In addition, hook no.5 also caught larger haddock than hook no. 6. There is, however, reason to question this weakly significant result as hook no. 5 is smaller than no. 6, and that it does not fit into the general picture.

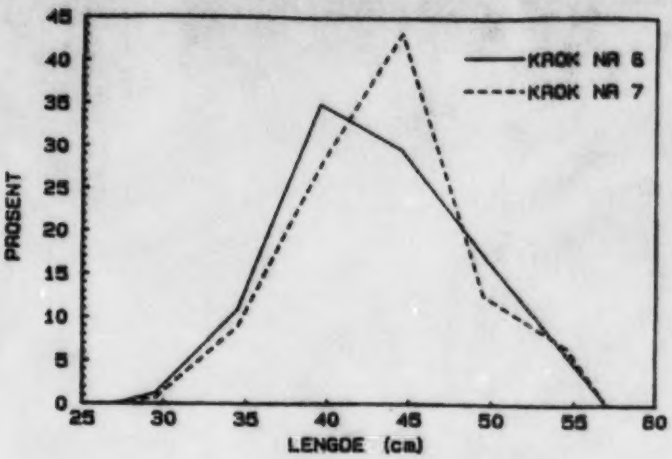
In the trials with 20 and 30 g baits there were no statistically significant differences with respect to either catch or length. However, there is reason to note that with 20 g baits hook no. 5 caught almost 19 percent more haddock than hook no. 6.

It therefore seems to be a connection between hook- and bait size with respect to efficiency as hook no. 5 was more effective than hook no. 6 with 10 g baits, while the two hooks caught exactly the same number of haddock with 30 g baits. In addition it appears as if the catch difference with 20 g baits lies somewhere between the differences with 10 and 30 g baits.

Comparison of hooks nos. 6 and 7.

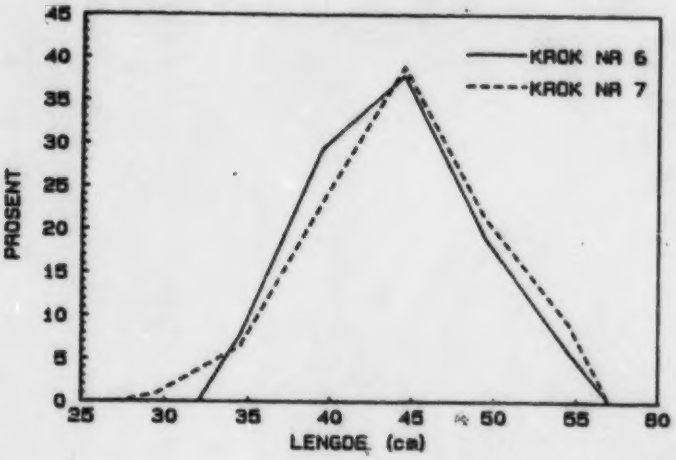
The results that are presented on the opposite side shows that there were no statistically significant differences between hooks nos. 6 and 7 either with respect to catch or length. From Fig. 2.2.16 it can be seen that there are quite large differences in the shape of the distribution curves. But according to a two-sample Kolmogorov - Smirnov test (SIEGEL 1956) the difference is not significant ($0.10<p<0.20$).

(See p.48)



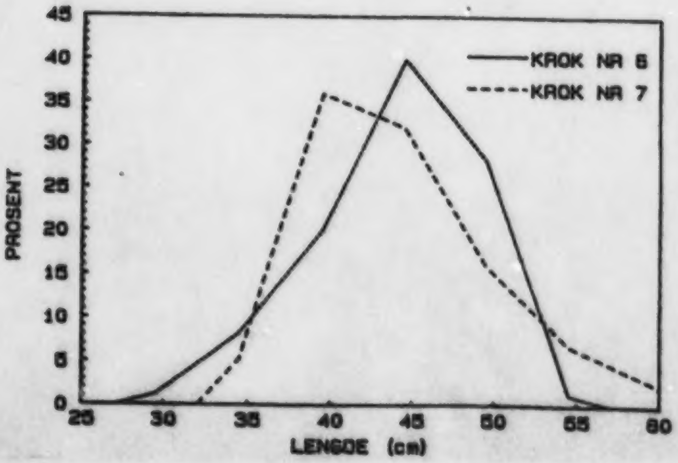
KROK NR	6	7
ANTALL HYSER	186	168
FISK PR KROK	.19	.16
FORSKJELL (%)	10.7	
FORTEGNSTEST	.258	
ANTALL MÅLT	172	134
MIDDELLENGDE	42.6	43.0
+/-95% KONF.	.78	.82
MANN-WHITNEY	.446	

Figure 2.2.14. Comparison of hooks nos. 6 and 7 with 10 g baits. Catch- and length data for haddock.



KROK NR	6	7
ANTALL HYSER	111	104
FISK PR KROK	.14	.13
FORSKJELL (%)	6.7	
FORTEGNSTEST	.582	
ANTALL MÅLT	116	108
MIDDELLENGDE	43.2	44.0
+/-95% KONF.	.89	.97
MANN-WHITNEY	.173	

Figure 2.2.15. Comparison of hooks nos. 6 and 7 with 20 g baits. Catch- and length data for haddock.



KROK NR	6	7
ANTALL HYSER	79	82
FISK PR KROK	.10	.10
FORSKJELL (%)	3.8	
FORTEGNSTEST	.800	
ANTALL MÅLT	85	76
MIDDELLENGDE	44.1	44.2
+/-95% KONF.	1.18	1.52[1]
MANN-WHITNEY	.313	

[1] FOR STOR SKEWNESS.

Figure 2.2.16. Comparison of hooks nos. 6 and 7 with 30 g baits. Catch- and length data for haddock.

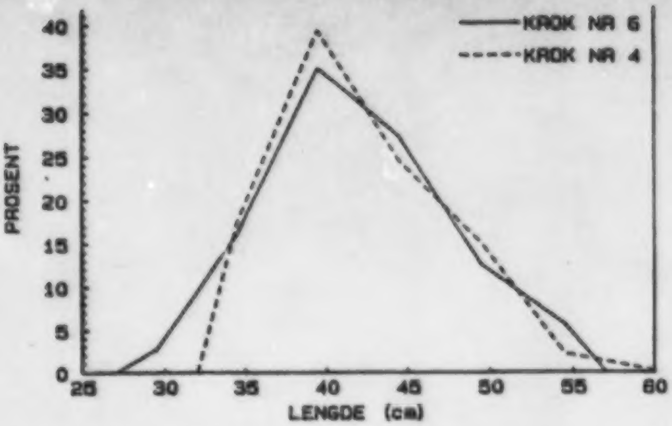
Comparison of hooks nos.4 and 6.

In the comparison with 10 g baits (Fig. 2.2.17) there was a significantly larger catch on hook no. 4 of ca 30 percent without there being any difference in length. With 20 and 30 g baits (Fig. 2.2.18 and Fig. 2.2.19) there were no statistically significant differences either with respect to length or catch. The results therefore confirm that the combination of hook - and bait size is of essential importance for the effectiveness. Otherwise it is interesting to note that there were no selectivity differences between hooks nos 4 and 6 in spite of the relatively large size differential between these hooks.

Briefly summarized, the results from the various trials show that there are no differences of importance in the selective properties of hooks nos. 4, 5, 6 and 7, and that hooks nos. 4 and 5 are more effective than hook no. 6, while hooks nos. 6 and 7 are approximately equally good. This is in agreement with the results for cod. However, a difference between cod and haddock is however that for cod the bait size has no influence on the relative difference in effectiveness between the hooks, while it is of considerable importance for haddock in that the catching ability of small hooks only is better in combination with small baits.

Other species.

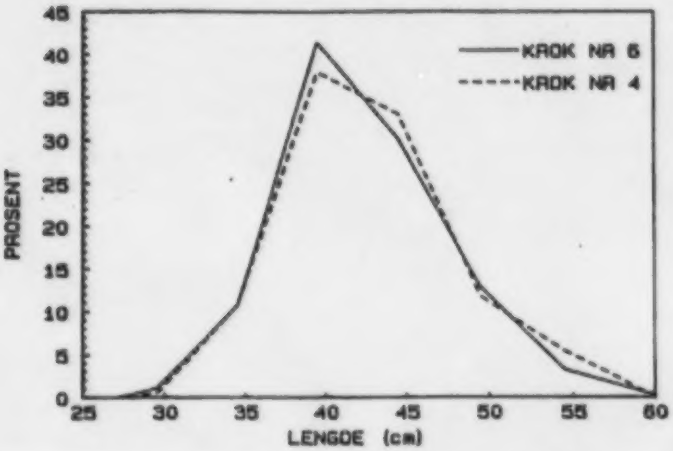
In Table 2.2.4 the number of pairs with haddock and other species is presented. In no cases were there any differences of importance in the number of pairs with non-target species on the hooks being compared. It therefore seems to be obvious that these other species did not have any substantial influence on the estimated catch differences.



ANTALL HYSER	231	304
FISK PR KROK	.34	.45
FORSKJELL (%)	31.6	
FORTEGNSTEST	0.000	
ANTALL MÅLT	215	272
MIDDELLENGDE	41.6	41.8
+/-95% KONF.	.74	.86
MANN-WHITNEY	.885	

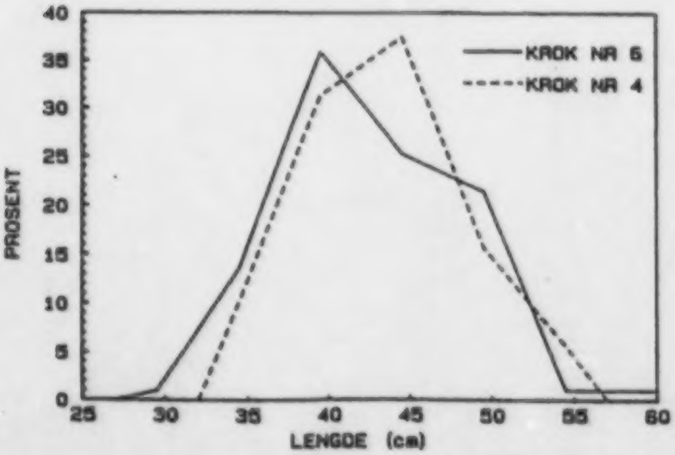
(See p.48)

Figure 2.2.17. Comparison of hooks nos. 4 and 6 with 10 g baits. Catch- and length data for haddock.



KROK NR	6	4
ANTALL HYSER	237	268
FISK PR KROK	.28	.32
FORSKJELL (%)	13.1	
FORTEGNSTEST	.068	
ANTALL MÅLT	186	203
MIDDELLENGDE	41.8	42.2
+/-95% KONF.	.73	.69
MANN-WHITNEY	.453	

Figure 2.2.18. Comparison of hooks nos. 4 and 6 with 20 g baits. Catch- and length data for haddock.



KROK NR	6	4
ANTALL HYSER	135	153
FISK PR KROK	.14	.16
FORSKJELL (%)	13.3	
FORTEGNSTEST	.210	
ANTALL MÅLT	103	128
MIDDELLENGDE	42.2	42.9
+/-95% KONF.	1.10	.86
MANN-WHITNEY	.241	

Figure 2.2.19. Comparison of hooks nos. 4 and 6 with 30 g baits. Catch- and length data for haddock.

The hook fastening point.

The results for the hook fastening point studies for haddock are presented in Table 2.2.5. Most of the haddock were hooked in the mouth, while the incidence of fish that had swallowed the hook was minimal. In contrast to the results for cod, the catch of haddock hooked in the body was of a certain importance. In total for all the comparisons it comprised nearly 10 percent of the catch, while in connection with high concentrations of haddock there were hauls when about 20 percent had been hooked in the body. (Compare Trial 64).

In Trials 65 and 67 there were no hooks that stood out as more effective than the others for catching haddock that had been hooked outside the mouth. It therefore seems to be obvious that the observed differences in effectiveness are due to variations in the catch of mouth hooked haddock.

In Trial 64 the catch of mouth-hooked haddock was in all cases greatest on hook no.4 with a catch difference of between 23 and 31 percent (p=0.002, p=0.024 and p=0.057, binomial test; the probability is arranged according to increasing bait sizes). In the comparisons with 20 and 30 g baits the catch of body-hooked haddock was , however, somewhat higher on hook no. 6 than hook no.4 (p=0.120 and p=0.166 respectively, the binomial test), so that there were no significant differences between the total catches (compare Fig.2.2.188 and Fig. 2.2.19). There could be several reasons for this, for example it could be imagined that hook no.6 is more effective for hooking haddock outside the mouth because it has a larger gap. But it is most likely that the difference is due to the fact that there were more "vacant" hooks of no.6 since no.4 hooked more haddock in the mouth.

Correspondingly high catch rates of haddock hooked outside the mouth have been found by HUSE (1979a) in the floating longline fishery which is the only commercial fishery especially directed at haddock. Catches of body-hooked haddock are therefore a factor that in most cases must be taken into consideration.

	10 g baits	20 g baits	30 g baits
Hook no. 6	41	25	10
Hook no.5	39	23	14
No.of pairs	276	222	131
Krok nr 6	30	19	17
Krok nr 7	37	18	12
Antall par	304	188	150
Krok nr 6	23	13	5
Krok nr 4	10	11	3
Antall par	403	397	247

Table 2.3.5 Hook fastening point - haddock.

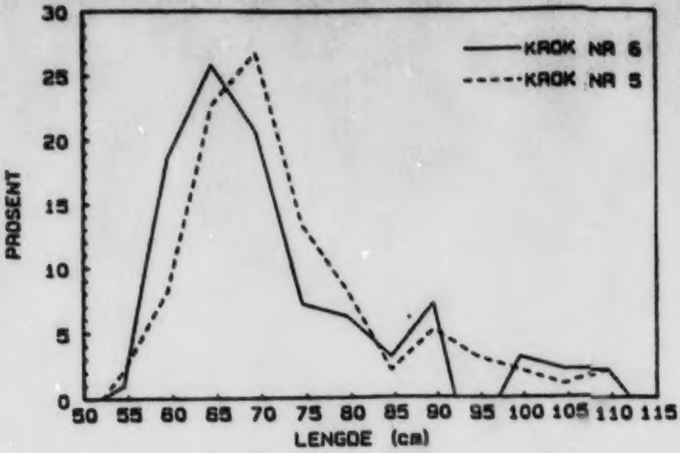
Bait (gram)	Hook no.	Hook fastening point Mouth	Swallowed	Body	Registered hooks
10	6	132	3	9	888
	5	165	10	5	887
20	6	111	0	8	736
	5	119	6	16	722
30	6	61	2	8	641
	5	59	3	9	645
10	6	167	7	12	974
	7	146	6	16	975
20	6	97	1	13	822
	7	88	2	14	807
30	6	72	2	5	800
	7	71	0	11	796
10	6	221	0	10	674
	4	289	1	14	672
20	6	195	1	41	841
	4	240	1	27	830
30	6	108	1	26	829
	4	137	0	16	818

Discussion.

The results for haddock agree well with the corresponding results for cod in that the selective properties of the hooks tested were approximately equal, hooks nos.4 and 5 were more effective than hook no.6 and hooks nos. 6 and 7 were approximately equally good. It therefore seems to be a reasonable assumption that it is the same properties of the hook that are decisive for the effectiveness both for cod and for haddock, namely the penetration ability.

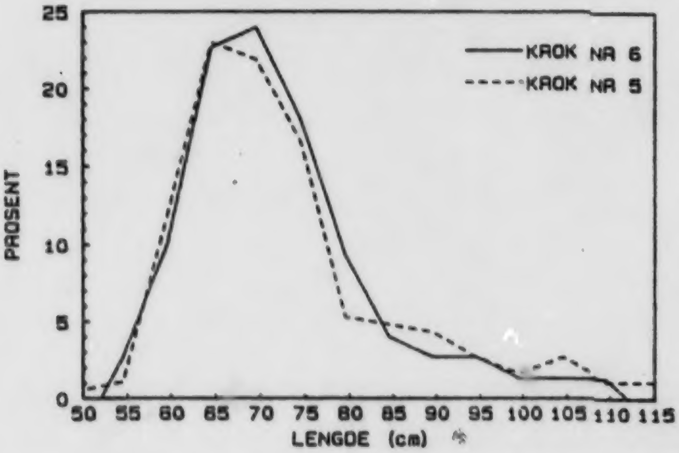
But on an important point there was a substantial difference between the results for cod and haddock. For cod the bait size had no influence on the relative catch difference between the hooks, while it was in contrast of great importance for the catch of haddock. The reason that small hooks were only more effective than larger hooks together with small baits could be that the behaviour of haddock towards the individual bait sizes was not equal. But the condition could also be due to purely physical properties with the different hook and bait combinations (i.e. factors such as length, width and weight). This will be discussed in the concluding discussion.

(See p.35)



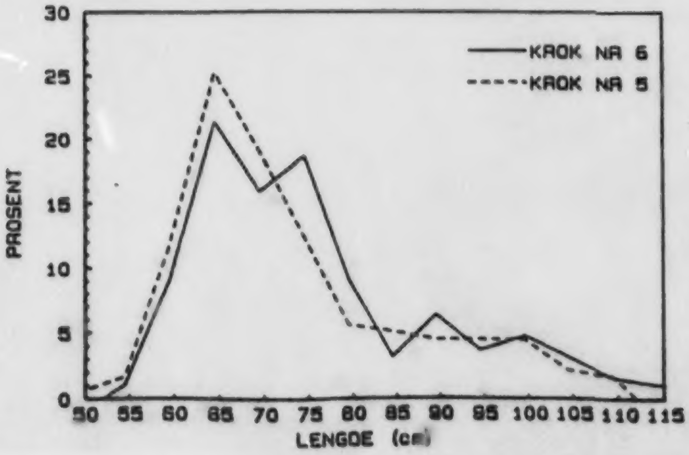
KROK NR	6	5
ANTALL TORSK	85	89
FISK PR KROK	.21	.22
FORSKJELL (%)	4.7	
FORTEGNSTEST	.719	
ANTALL MÅLT	97	97
MIDDELLENGDE	70.2	71.9
+/-95% KONF.	2.69	2.63
MANN-WHITNEY	.171	

Figure 2.2.20. Comparison of hooks nos.5 and 6 with 10 g baits. Catch- and length data for cod.



KROK NR	6	5
ANTALL TORSK	148	180
FISK PR KROK	.17	.21
FORSKJELL (%)	21.6	
FORTEGNSTEST	.043	
ANTALL MÅLT	150	187
MIDDELLENGDE	71.5	72.6
+/-95% KONF.	1.71	1.92
MANN-WHITNEY	.952	

Figure 2.2.21. Comparison of hooks nos 5 and 6 with 20 g baits. Catch- and length data for cod.



KROK NR	6	5
ANTALL TORSK	173	174
FISK PR KROK	.21	.21
FORSKJELL (%)	.6	
FORTEGNSTEST	.972	
ANTALL MÅLT	185	176
MIDDELLENGDE	74.9	73.3
+/-95% KONF.	1.96	2.08
MANN-WHITNEY	.070	

Figure 2.2.22. Comparison of hooks nos. 5 and 6 with 40 g baits. Catch- and length data for cod.

2.2.4 The Gryllefjord trials.

These trials were carried out in February and March 1981. The catch consisted chiefly of cod on their spawning migration to Lofoten, so these fish were considerably larger and in a very different physiological state than those caught in the Vardö area. In addition to cod, the catch consisted of haddock, cusk, halibut and squid, but the incidence of these was so small that they will not be further evaluated.

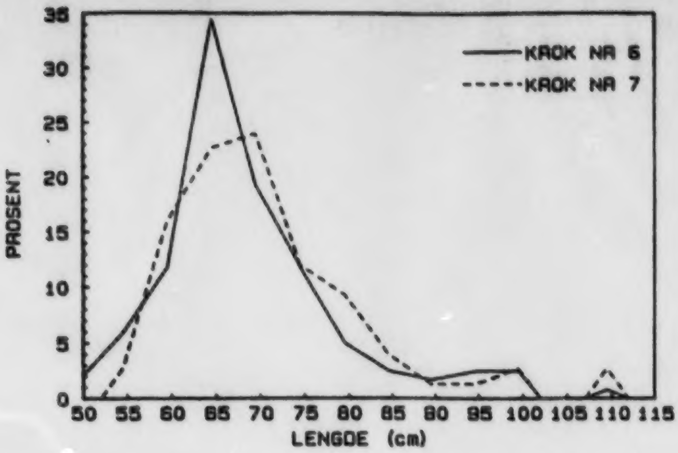
In this period trials were made with 40 gram baits instead of 30 gram baits. This is associated with the fact that 40 g baits are standard in the area, and that it was desirable to be able to compare the standard bait with other bait sizes.

Comparison of hooks nos. 5 and 6.

The results of the hook comparisons are presented in figures 2.2.20 to 2.2.22. The material in the comparisons with 10 g baits was collected in two sets while for those with 20 and 40 g baits an extra set was made.

In the comparisons with 10 and 40 g baits, the catches were practically the same on the two hooks. In contrast, there was a significantly increased catch on hook no.5 with 20 g bait. With respect to the length of the cod, there were no statistically significant differences in any of the comparisons.

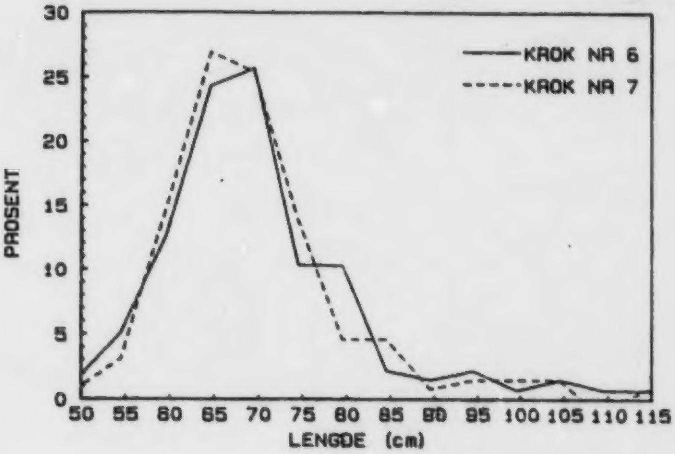
The results therefore show that there are no differences in the selective properties of hooks nos 5 and 6 which is in agreement with the results in the Vardö trials. In contrast it can appear as if the combination of hook- and bait size has an influence on the difference in effectiveness between the hooks.



KROK NR	6	7
ANTALL TORSK	81	63
FISK PR KROK	.13	.10
FORSKJELL (%)	28.6	
FORTEGNSTEST	.115	
ANTALL MÅLT	119	75
MIDDELLENGDE	68.1	69.9
+/-95% KONF.	1.90	2.86
MANN-WHITNEY	.155	

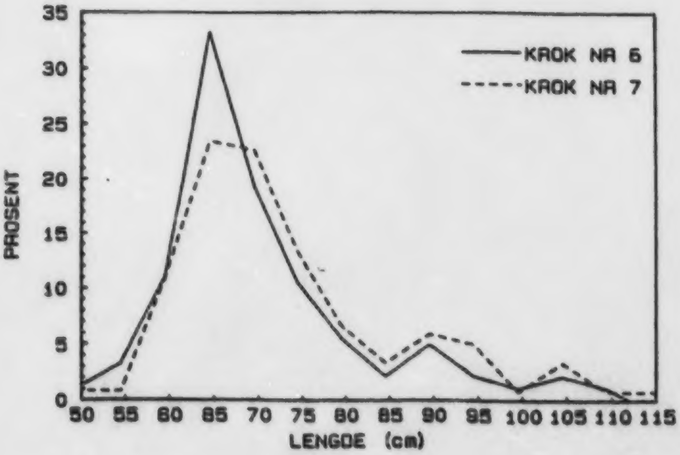
(See p.35)

Figure 2.2.23. Comparison of hooks nos.6 and 7 with 10 g baits. Catch- and length data for cod.



KROK NR	6	7
ANTALL TORSK	117	105
FISK PR KROK	.15	.13
FORSKJELL (%)	11.4	
FORTEGNSTEST	.372	
ANTALL MÅLT	136	130
MIDDELLENGDE	69.9	69.3
+/-95% KONF.	2.95	1.80
MANN-WHITNEY	.756	

Figure 2.2.24. Comparison of hooks nos. 6 and 7 with 20 g baits. Catch- and length data for cod.



KROK NR	6	7
ANTALL TORSK	166	118
FISK PR KROK	.19	.13
FORSKJELL (%)	40.7	
FORTEGNSTEST	.001	
ANTALL MÅLT	180	119
MIDDELLENGDE	70.1	72.5
+/-95% KONF.	1.64	2.36
MANN-WHITNEY	.094	

Figure 2.2.25. Comparison of hooks nos. 6 and 7 with 30 g baits. Catch- and length data for cod.

Comparison of hooks nos. 6 and 7. (p.37)

In the comparisons with 10 and 20 g baits (Figs. 2.2.23 and 2.2.24) there were no statistically significant differences between the catches on hooks nos. 6 and 7, but in both cases there were somewhat higher catches on hook no. 6. With 40 g baits (Fig. 2.2.25) there was, however, a significantly greater catch on hook no.6 of 40 percent. There were no differences in the lengths of the cod in any of the comparisons.

The results therefore show that hooks nos. 6 and 7 have approximately equal selective properties, but that hook no.6 is more effective than hook no. 7. For comparison, the two hooks were approximately equally effective in the Vardö trials.

Other species.

In Table 2.2.6 the number of pairs with cod and other species is shown. In no cases were there differences of importance in the number of pairs with non-target species on the compared hooks.
It therefore seems to be obvious that the other species have not had any influence of importance on the estimated catch differences.

The hook fastening point.

The results of the hook fastening studies are shown in Table 2.2.7. Similar to the Vardö trials most of the cod were hooked in the mouths also in this area. Some cod had also swallowed the hook, while the incidence of fish hooked in the body was minimal.

As shown in the table there was a marked similarity between the catch of fish that had swallowed the hook in the various comparisons. The differences in effectiveness that were observed are therefore due to variation in the catch of mouth-hooked fish. This means that the hooks had different hook fastening points in

Table 2.2.6. Other species. The table shows the total number of cod in the various comparisons and the number of pairs with non-target species on the different hooks.

	10 gram bait	20 gram bait	40 gram bait
Hook no.6	24	23	22
Hook no.5	21	19	29
No. of pairs	154	289	309
Hook no.6	5	15	9
Hook no.7	9	14	18
No.of pairs	137	201	252

Table 2.2.7. Hook fastening points - cod

Bait	Hook	Hook fastening point			Registered
(gram)	no.	Mouth	Swallowed	Body	hooks
10	6	70	11	4	404
	5	79	10	0	407
20	6	120	26	2	852
	5	151	27	2	859
40	6	125	44	4	813
	5	133	38	3	820
10	6	68	10	3	647
	7	53	10	0	644
20	6	94	15	7	794
	7	76	22	7	804
40	6	124	40	2	893
	7	78	39	1	883

comparisons where catch differences were demonstrated.

In these studies,hooks that had been completely swallowed (into the stomach) comprised a considerably greater part of the category swallowed than in the Vardö trials where it practically did not occur. When a hook has been swallowed into the gullet or the stomach, there is probably a small chance that the fish will escape regardless of hook type. Completely swallowed hooks are therefore probably a contributing factor to the fact that the number of fish that had swallowed the hook was about the same on the various hooks.

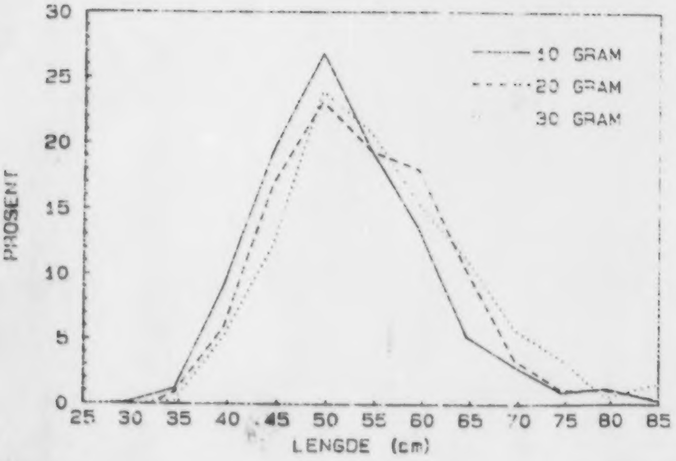
Discussion.

The results in the Gryllefjord trials are not completely unambiguous. In the comparisons between hooks nos. 5 and 6 there were only catch differences with 20 g baits, while for hooks nos. 6 and 7 ,on the other hand, the greatest differences in catches were found with 10 and 40 g baits. It is difficult to say why this is so. The tendency is, however, the same as in the Vardö trials in that smaller hooks were more effective than larger hooks. On the other hand, other factors other than the penetrating ability seem to have been of greater importance for the effectiveness of the various hooks. For example, the relatively large difference in effectiveness between hooks nos.6 and 7 could hardly be due to the penetrating ability of the hook since there is no difference between the barb width of these hooks. A possible reason for the fact that the penetrating ability was not of such great importance as in the Vardö trials, could be that the cod in the Gryllefjord area attacked hook and bait with greater force. In that way the hooking will to a greater degree depend on the point of penetration and not if the fish attacks the line with a force that is greater or less than the penetrating force of the hook. Seen on the background that the various hook types had different fastening points in the fish mouth, it is reason to believe that the point of penetration was of the greatest importance in these studies. With respect to which factors on the hook that could influence (p.39) the point of penetration, the gap is probably of greatest importance.

The results of the hook comparisons in the Vardö - and Gryllefjord trials show some interesting similarities. Small hooks were in both areas more effective than larger hooks, there were no differences between the selective properties of the hooks tested and hook no.5 seems to be a very good "all round" hook. Otherwise the results show that in the choice of an optimal hook one must take into consideration both the point where the hook penetrates the mouth and its penetrating ability.

Table 2.3.1. Catch data from Trial 65.

Bait pairs AGNPAR	No. of cod ANTALL TORSK	Fish per hook FISK PR KROK	Difference % FORSKJELL (%)	T-Test (pairs) T-TEST (PAR)
10 GRAM	566	.33	18.2	.041
20 GRAM	479	.29		(36)
10 GRAM	568	.32	60.0	0.000
30 GRAM	355	.20		(37)
20 GRAM	457	.29	37.7	0.000
30 GRAM	332	.21		(34)



Bait size	10	20	30
No.measured	693	558	406
Mean length	51.6	53.3	54.8
+/-95% Confid.	.65	.73	.92
Krusk--Wall	0.000		
Mann-Whitney	*	*	0.000
(* marks	*	0.000	*
test variab)	.043	*	*

Figure 2.3.1. Length data from Trial 65.

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2.3 THE BAIT COMPARISONS - RESULTS AND DISCUSSION

The same data material was used for both the hook and the bait comparisons (see Section 2.1.4 on the experimental setup). This means that in each experimental series the different baits were compared with two hook sizes. The catch- and length data on the hooks being compared are, however, combined in all cases where there was a statistical basis for it (See Section 2.1.10).

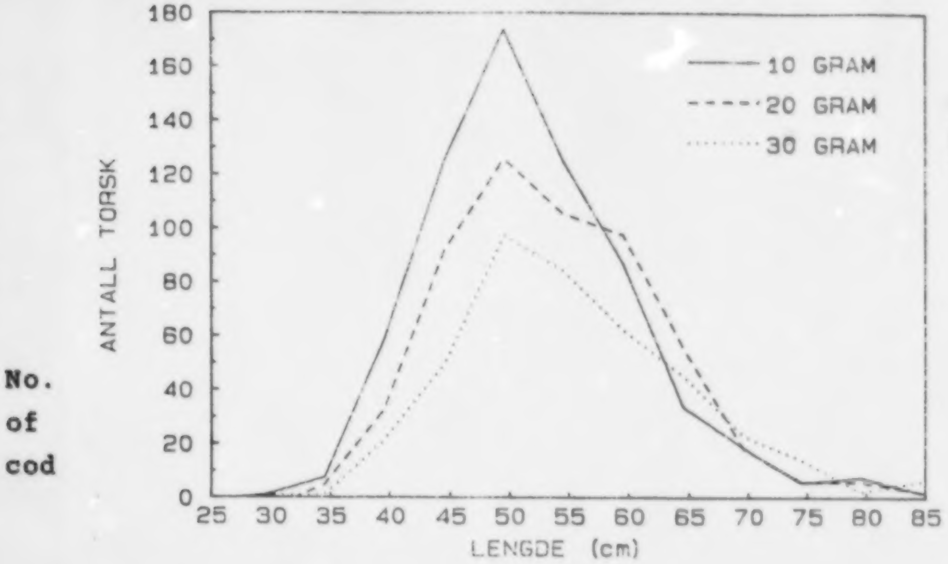
2.3.1 Cod - The Vardö Trials.

The results of the bait comparisons are presented in a way corresponding to the hook trials, that is by trial series, and cod and haddock separately. With the exception of the hook fastening studies, Trial 64 is not included in the results for cod due to the small size of the data material.

Trial 65.

In this series of fishing trials both catch- and length data for the two hooks have been combined. The catch results are presented in Table 2.3.1. In the comparison between 10 and 20 gram baits there was an increased catch for 10 g baits of 18.2 percent. The probability of the results having occurred by chance is calculated to 0.041 with the help of paired T-tests. The number in brackets, in this case 36, gives the number of pairs compared to obtain this result. Otherwise it can be seen from the table that 30 g baits were considerably less effective than both 10 and 20 g baits.

The relative length distributions are presented in Fig. 2.3.1. It can be seen that the length of the fish increased with the bait size. Between 10 and 20 g baits there was a difference in mean length of 1.7 cm and between 20 and 30 g baits of 1.5 cm. (p.41)



Figur 2.3.2. Fangstkurver fra Forsøk 65.
Figure 2.3.2. Catch distribution curves from Trial 65.

Table 2.3.2. Catch data from Trial 67.

Bait pair	No. of cod	Fish per hook	Difference	Binomial test
10 g	541	.27	15.8	.025
20 g	418	.23		
10 g	541	.27	42.6	.000
30 g	371	.19		
20 g	418	.23	23.1	.004
30 g	371	.19		

The results of the Kruskal - Wallis and Mann - Whitney tests show that all the mean lengths were significantly different. (The stars indicate which distributions were tested against each other with the Mann - Whitney test; for example the test result 0.043 is a comparison between 20 and 30 g baits).

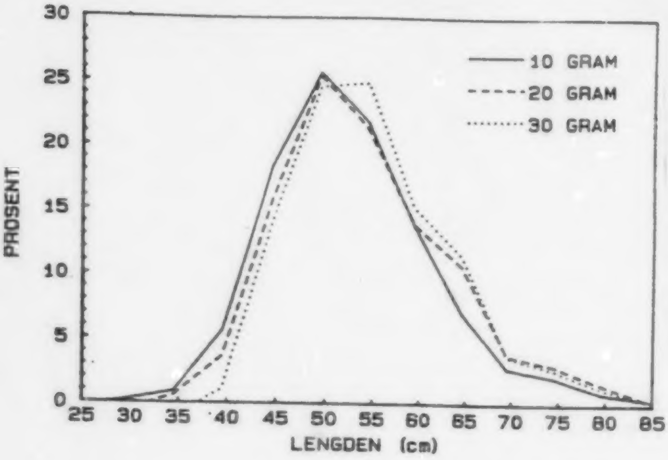
Fig 2.3.2 shows the catch curves for 10, 20 and 30 g baits (the curves were constructed by adjusting the relative length distributions so that the area under the curves corresponds to the catch). From the figure it can be seen that 10 g baits were more effective than 20 g baits for fish under ca 58 cm, while 20 g baits gave somewhat higher catches above this length. Thirty gram baits were, however, less effective than both 10 and 20 g baits over almost the whole length spectrum.

The results of the comparisons show that 10, 20 and 30 g baits possess different selective properties , and that the difference is due to the fact that small baits are more effective for smaller fish.

Trial 67.

In this experimental series there were a number of tangles and they were so distributed that the data material for paired comparisons was almost halved relative to the total experimental volume. In addition, the data were quite contradictory. In this series it was therefore decided to calculate the relative catch differences on the basis of the catch rates in the total data material, i.e. the same data used for the hook comparisons. The catches on hooks nos 6 and 7 were combined, and the results of the analysis are presented in Table 2.3.2. For statistical testing of the catch differences the binomial test was used.

From the table it can be seen that there were significant catch differences between all bait sizes. Similar to the (p.42) preceding experimental series, 10 g baits were most effective, followed by 20 g baits and then 30 g baits.

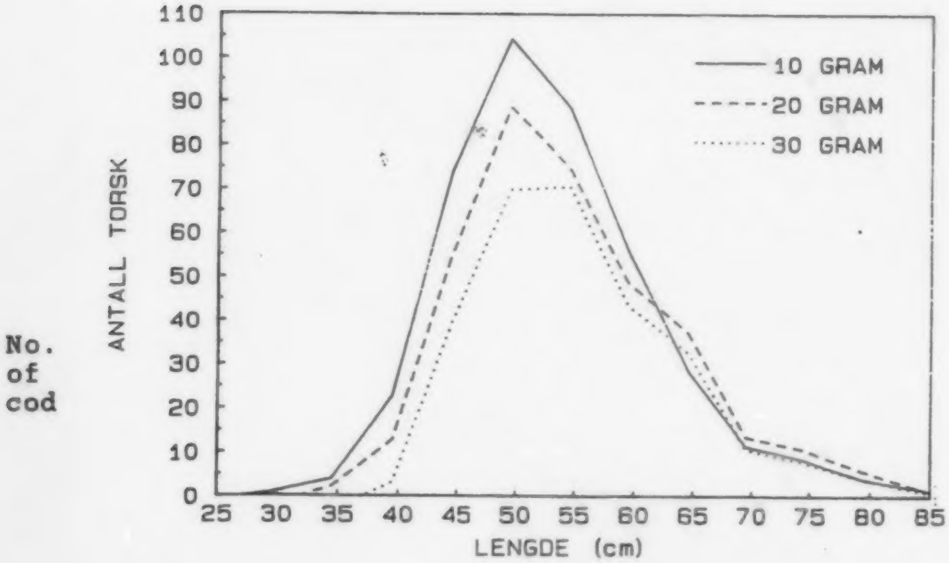


Bait size	10	20	30
No.measured	536	497	374
Mean length	52.7	54.1	55.0
+/-95%Confid.	.80	.78	.88
Krusk.-Wall.		0.000	
Mann-Whitney	*	*	.004
(* marks test	*	0.000	*
variab.)	.120	*	*

Figur 2.3.3. Lengdedata fra Forsøk 67.

Length (cm)

Figure 2.3.3. Length data from Trial 67.



Figur 2.3.4. Fangstkurver fra Forsøk 67.

Length (cm)

Figure 2.3.4. Catch curves from Trial 67.

In Fig. 2.3.3 the length results for the three bait sizes have been presented. Also here the mean length increased with the bait size. The difference between 20 and 30 g baits was , however, not significant. From the catch curves in Fig. 2.3.4 it can be seen that the three baits were approximately equally effective for fish that were larger than ca 60 cm, while there were relatively large differences for smaller fish.

The results in this experimental series are essentially in agreement with the results in Trial 65. It therefore seems to be obvious that 10, 20 and 30 g baits have different selective properties, and that the difference consists in that small baits are more effective than for smaller fish. In addition,there are indications that the three bait sizes are approximately equally effective for larger fish.

Saturation

Gear saturation occurs when there are more fish present than the gear has capacity to catch. In comparative fishing trials this can manifest itself in two ways:

(i) If there are no differences in selectivity between the parameters in question, as for example in the hook comparisons, the relative catch differences can be underestimated. This will be further discussed in the concluding discussion.

(ii) If there are differences in the selective properties of the parameters, it can lead to the selectivity differences being overestimated. Transferred to the actual conditions this will mean that due to the fact that 10 g baits were more effective for smaller fish than the other bait sizes, it could have lead to the catch of large fish being underestimated relative to 20 and 30 g baits as a result of the small fish "occupying" the hooks. (p.43) Saturation will express itself in that the sizes of fish in cells with high catch rates are smaller than in cells with low catches. This is of course the case only if the same is not the case for the

Table 2.3.3. The mean length (in cm) of cod in cells with different number of length measurements. Data from Trial 65.

10 g baits			20 g baits			30 g baits		
No.per cell	Nos measured	Mean length						
1 - 12	156	53.8	1 - 11	153	52.9	1 - 7	98	55.9
13 - 16	152	52.6	12 - 15	150	52.0	8 - 11	117	54.2
17 - 25	153	50.0	16 - 20	126	53.4	12 - 15	92	54.1
> 25	232	50.5	> 20	130	53.9	> 15	99	55.0
p<0.001			p=0.262			p=0.900		

Table 2.3.4. Mean length (in cm) of cod in cells with different number of length measurements. 1

[illegible]

(See above)

10 grams agn			20 grams agn			30 grams agn		
Ant. pr celle	Ant. målt	Middel lengde	Ant. pr celle	Ant. målt	Middel lengde	Ant. pr celle	Ant. målt	Middel lengde
1 - 10	142	52.2	1 - 9	113	53.2	1 - 8	114	54.4
11 - 14	127	50.4	10 - 12	138	55.6	9 - 10	127	54.4
15 - 20	103	52.7	13 - 16	133	53.1	11 - 12	70	56.8
> 20	164	55.0	> 16	113	54.4	> 12	63	55.4
p<0.001			p=0.120			p=0.034		

other bait sizes.

To study if saturation has any influence on the results, the cells were divided into four groups according to how many length measured fish there were in the cell (practically all the fish in a cell were measured). This was possible because a division was made between the fish in the different cells during the length measurements. The division was made so that the number of fish in each group was as equal as possible. The Kruskal - Wallis test was used to study if the mean lengths in different groups were different.

The results of the analyses for Trial 65 are presented in Table 2.3.3 which gives the division limits, number of length measurements and the mean lengths. In the 10 g groups there were significant differences between the mean lengths, and the smallest fish were caught in cells with relatively high catch rates. With 20 and 30 g baits there were not corresponding tendencies.

The results of the corresponding analyses for Trial 67 are presented in Table 2.3.4. Here there were significant differences both in the 10 and 30 g groups. However, there were no tendencies that the smallest fish on hooks with 10 g baits were caught in cells with many, on the contrary the smallest fish were caught in cells with relatively little fish. Saturation has therefore scarcely occurred in this experimental series. The variation in the mean lengths therefore probably mirror an uneven distribution of fish in the sea. When the mean lengths did not fluctuate evenly for the different bait sizes, it could be due to the many tangles in this series so that cells that were close to each other in space have not been included in the corresponding groups.

Uneven distribution of the fish in the sea could also have been the reason for the differences in the 10 g groups in Trial 65. It is , however, more likely that it is due to saturation, both since cells with different bait sizes that were close to each other in space essentially came in corresponding groups, and because the middelverdi +/-95% konfidensintervall.

Mean value +/- confidence interval.

Bait (g)	Nos.	Length (cm)	Weight (kg)	Liver (g)	Condition factor
10	51	49.4 +/-1.9	1.10 +/-0.13	63.3 +/-10.3	.867 +/-.018
20	63	49.8 +/-1.9	1.11 +/-0.13	63.0 +/-9.2	.847 +/-.018
39	40	54.8 +/-2.6	1.42 +/-0.21	88.6 +/-15.5	.824 +/-.037

Table 2.3.6. Stomach fullness

Degree of fullness	10 g bait Nos.	%	20 g bait Nos.	%	30 g bait Nos.	%
grad	Antall	Prosent	Antall	Prosent	Antall	Prosent
Empty (1)	27	53	39	62	29	73
Rest (2)	21	41	15	24	24	20
Half full (3)	3	6	6	10	10	5
Full (4)	0	0	0	0	0	0
Bulging (5)	0	0	0	0	0	0
Inside-out (6)	0	0	3	5	1	3

Tabell 2.3.7 Mageinnhold

Table 2.3.7. Stomach contents

Contents	No. of stomachs
Krill	40
Not ident.	6
Polychaeta	2
Hermit crabs	1
Fish eggs	1
Starfish	1
Bottom substrate	2

catch rates in this experimental series were higher than in Trial 67 (see the number of fish measured by length in the different groups in the table).

If we compare these analytical results with the catch distribution curves in Figs. 2.3.2 and 2.3.4, the impression that the various bait sizes are approximately equally effective for larger fish is being reinforced.

Biological samples.

The results of the biological studies are presented in Table 2.3.5. There was practically no difference in either length, weight (round weight), liver weight or condition factor of the fish samples caught on 10 and 20 g baits. The fish caught on 30 g baits were somewhat larger than on the other bait sizes, but had in contrast a somewhat lower condition factor. However, the difference in condition factor was not significant (p=0.147, the Kruskal - Wallis test).

From Table 2.3.6 it can be seen that 53 percent of the cod caught on 10 g baits did not have food in the stomach. On the other bait sizes there were somewhat more fish with empty stomachs.
A Chi - square test applied on the contingency table of fish with stomach contents (2+3+4+5) and fish with empty stomachs (1), showed, however, that the differences between the various bait sizes were not significant (p=0.106).

Table 2.3.7 shows what the stomach content consisted of. The most common stomach content was krill. In six stomach there was unidentifiable material that mostly looked like almost completely digested fish.

The sample size of fish that had swallowed the hook is too low to be separately analyzed for each bait size. They were (p.45) therefore combined and the result of the analyses between mouth - hooked and hook swallowed fish is presented in Table 2.3.8.

Table 2.3.8. Biological samples of cod. The data have been sorted by mouth - hooked and hook - swallowed fish. The measurements are given as mean value +/-95% confidence interval.

Fastening pt.	Nos	Length (cm)	Weight (kg)	Liver (g)	Cond. fact.
Mouth	106	51.2+/-1.6	1.22+/-0.11	70.9+/-8.0	.857+/-.013
Swallowed	38	49.8+/-2.4	1.09+/-0.16	60.7+/-11.8	.839+/-.019
Mann-Whitney		0.426	0.260	0.226	0.034

Table 2.3.9. Hook fastening point - cod.

Bait Size	Hook fastening point				Registered hooks
	Mouth		Swallowed		
	Nos.	%	Nos.	%	
10 gram	1136	81	262	19	5368
20 gram	861	74	296	26	5284
30 gram	640	72	245	28	5450

(Formally it is not correct to combine the data from the various bait sizes, and the results must therefore be used with certain reservations). There were not statistically significant differences either with respect to length, weight or liver weight. In contrast, fish that had swallowed the hook had a significant lower condition factor than mouth - hooked cod. The reason that a fish with a lower condition factor to a larger degree would swallow the hook, could be that this fish has a higher eating motivation. A similar result was reported by FERNÖ, SOLEMDAL & TILSETH (1981), who found that whiting that swallowed the bait had lower liver weight than other whiting.

The hook fastening point.

In Table 2.3.9, the summed up hook fastening points from Trial 64, Trial 65 and Trial 67 are presented (more detailed results are given in Table 2.2.2 in connection with the hook comparisons). The table shows the observed values and the percentage share they constituted of the catch. The share of mouth - hooked fish was considerably higher on 10 g baits than on 20 and 30 g baits (p<0.001, the Chi - square test). In contrast, there were no significant differences between the catch (numbers) of cod that had swallowed 10 g baits and the other bait sizes (p=0.113 and p=0.378 in the comparisons with respectively 20 and 30 g baits respectively; the binomial test). It therefore seems to be obvious that with 10 gram baits the hook has another fastening point than with 20 and 30 g baits.

Twenty gram baits caught 34.5 percent more mouth - hooked fish (p<0.001, the binomial test), and 20.8 percent more fish that had swallowed the hook than 30 g baits (p=0.012). The share of fish that had swallowed the hook and of fish that were mouth - hooked was in contrast not different for the two bait sizes (p=0.378, the hi-square test). It therefore appears that the hook has approximately the same fastening point with 20 and 30 g

(p.46)

baits.

The results of the fishing trials show that the better fishing power of 10 g baits was for smaller fish. A possible explanation for the higher share of mouth - hooked fish on 10 g baits could therefore have been that smaller fish more seldom swallow hook and bait. However, the biological studies did not show that there were statistical differences in the lengths of mouth - hooked and hook - swallowed fish. On the contrary, there was a tendency that fish that had swallowed the hook were somewhat smaller.

There therefore remains two possible explanations for the variations in the share of mouth - hooked and hook - swallowed fish on the various bait sizes. It can either be due to different behaviour of the cod towards the individual bait sizes, or it can be due to physical properties of the baits (ie factors such as length, width and weight).

Summary.

The results of the bait comparisons show that there are differences between the selective properties of 10, 20 and 30 gram baits. The reason for the differences is chiefly that small baits are more effective for catching small fish. The effectiveness for larger fish seems to be about the same for 10 and 20 gram baits. The results also give an indication that the effectiveness of 30 g baits approach that of the other bait sizes with increasing size of the fish.

It could be that there are two reasons for small baits being more effective than large baits: (1) Small baits give a higher probability of the fish being hooked, or (2) more fish attack small baits. Neither the biological studies nor the hooking point results give any basis for drawing any definite conclusions. Which hypothesis is the most probable will be discussed in the context of the behaviour studies (Chapter 3).

From Trial 65, hook no.6.

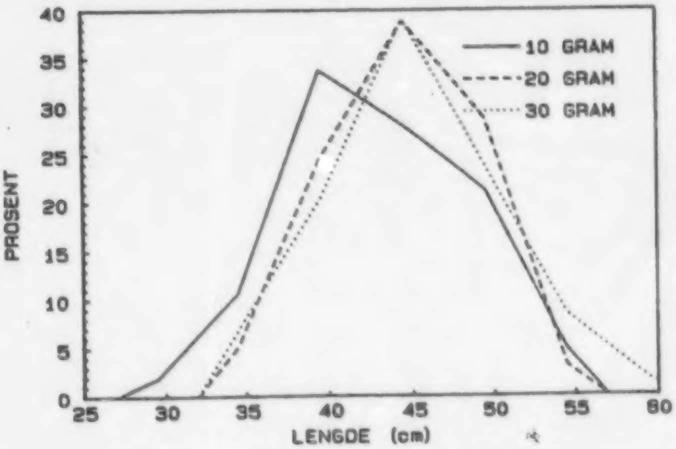
AGNPAR	ANTALL HYSER	FISK PR KROK	FORSKJELL (%)	T-TEST (PAR)
10 GRAM	107	.16	.9	.947
20 GRAM	106	.16		(28)
10 GRAM	107	.14	64.4	.006 1)
30 GRAM	65	.09		(31)
20 GRAM	95	.17	50.8	.013 1)
30 GRAM	63	.12		(23)

1) FOR STOR SKEWNESS

From Trial 65, hook no.5. 5.

AGNPAR	ANTALL HYSER	FISK PR KROK	FORSKJELL (%)	T-TEST (PAR)
10 GRAM	146	.20	15.9	.198
20 GRAM	126	.17		(31)
10 GRAM	133	.21	129.3	0.000
30 GRAM	58	.09		(27)
20 GRAM	118	.20	81.5	.001
30 GRAM	65	.11		(25)

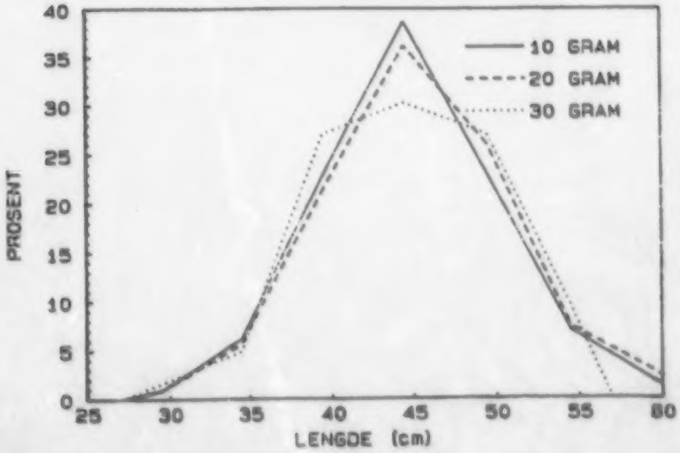
(See p.67)



AGNSTØRRELSE	10	20	30
ANTALL MÅLT	104	96	59
MIDDELLENGDE	42.9	44.3	44.5
+/-95% KONF.	1.09	.89	1.40
KRUSK.-WALL.	.070 1)		
MANN-WHITNEY	*	*	.041
(* markerer	*	.067	*
testvariab.)	.882	*	*

1) IKKE GRUNNLAG FOR PARVIS TESTING

Figure 2.3.5. Length data from Trial 65, hook no.6.



AGNSTØRRELSE	10	20	30
ANTALL MÅLT	114	108	83
MIDDELLENGDE	44.4	44.8	44.5
+/-95% KONF.	.99	1.05	1.38
KRUSK.-WALL.	.839 1)		
MANN-WHITNEY	*	*	.555
(* markerer	*	.758	*
testvariab.)	.856	*	*

1) IKKE GRUNNLAG FOR PARVIS TESTING

Figure 2.3.6. Length data from Trial 65, hook no.5.

2.3.2. Haddock - The Vardö Trials.

Trial 65

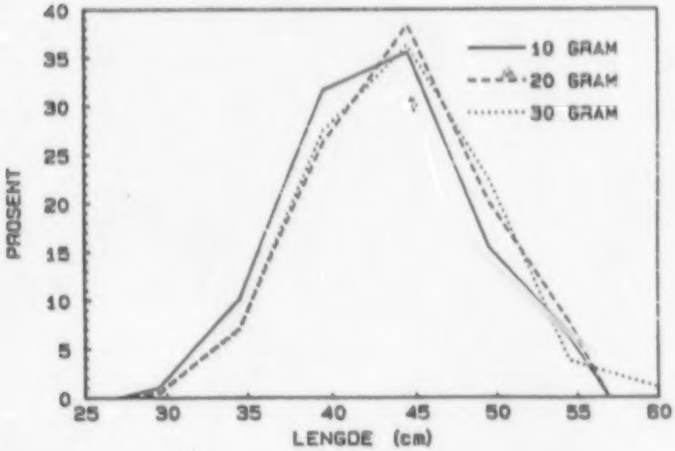
In this series of fishing trials, both the catch - and length data have been processed separately for each type of hook since there was not a statistical basis for combining the data. The catch results for hook no.6 are presented in Table 2.3.10 and for hook no. 5 in Table 2.3.11. In the comparisons between 10 and 20 g baits, there were no statistically significant differences with any of the hook sizes. On the other hand, thirty gram baits turned out to be much less effective than the two other bait sizes. (From Table 2.3.10 it can be seen that it was too much skewness in the two differential distributions for the test result to be trusted. But since the probabilities in both cases are far enough from the rejection limits , it does not mean anything for the conclusions made. Wilcoxon's test for paired comparisons, which does not presuppose normal distribution, gave the following results: p=0.003 and p=0.014).

The length results for hooks nos.6 and 5 are presented in respectively Fig. 2.3.5 and Fig. 2.3.6. There were no statistically significant differences between the mean lengths with any of the hooks, and from the figures it can be seen that the curves almost fall together over the whole length spectrum except for the length distribution for 10 g baits with hook no. 6. Fig. 2.3.5 shows that the Mann - Whitney test resulted in rejection of the comparison between 10 and 20 g baits. However, it is the Kruskal - Wallis test that is to be used as basis for the conclusion.

The results of the bait comparisons show that there are no significant differences in the selective properties of 10, 20 and 30 g baits, but that 30 g baits are considerably less effective than the other bait sizes.

Table 2.3.12. Catch data from Trial 67.

Bait pairs AGNPAR	No.of haddock ANTALL HYSER	Fish per hook FISK PR KROK	Difference(%) FORSKJELL (%)	T-Test (Pair) T-TEST (PAR)
10 GRAM	255	.17	32.1	.002
20 GRAM	193	.13		(32)
10 GRAM	274	.18	122.8	0.000
30 GRAM	123	.08		(32)
20 GRAM	170	.13	56.0	.013
30 GRAM	109	.08		(24)



(See p.67)

AGNSTØRRELSE	10	20	30
ANTALL MÅLT	306	224	180
MIDDELLENGDE	42.8	43.6	44.1
+/-95% KONF.	.57	.68	.94
KRUSK.-WALL.	.043		
MANN-WHITNEY	*	*	.088
(* markerer	*	.018	*
testvariab.)	.484	*	*

Fig. 2.3.7. Length data from Trial 67.

Trial 67.

In this fishing trial series, both catch - and length data on the hooks being compared are summarized. The catch results are shown in Table 2.3.12. In contrast to the preceding experimental series, the catch on 10 g baits was considerably higher than on 20 g baits, while 30 g baits also here were considerably poorer than the two other bait sizes. From the length results in Fig. 2.3.7 it can be seen that the mean length increased somewhat with the bait size. However, the difference was not large : Between 10 and 20 g baits it was 0.8 cm and between 20 and 30 g baits 0.5 cm.

The results therefore indicate that there are selectivity differences between 10, 20 and 30 g baits, but that they are small. On the other hand there are considerable differences in the effectiveness of the three bait sizes, with 10 g baits as the most effective.

Trial 64.

In this experimental fishing series the catch data are processed for each hook, while the length data have been combined. The catch results for hooks nos. 6 and 4 are presented in respectively Table 2.3.13 and Table 2.3.14. The catch rates in this series were considerably higher than in the two preceding, for example the catch rate for 10 g baits on hook no.4 was 0.47 fish per hook. The catch results are also quite unambiguous (all $p>0.006$). Similar to the preceding series, the catch on 10 g baits was considerably higher than on the two other bait sizes, while 20 g baits in turn were considerably more effective than 30 g baits. From Fig. 2.3.8 it can be seen that the difference was not more than one half cm between 10 and 20 g baits and correspondingly between 20 and 30 g baits.

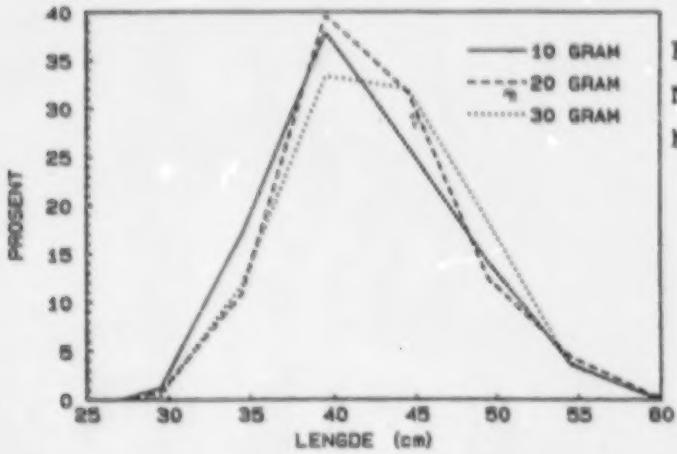
The results of the comparisons therefore shows that there are large differences between the three bait sizes. On the contrary,

Table 2.3.13. Catch data from Trial 64, hook no.6

AGNPAR	ANTALL HYSER	FISK PR KROK	FORSKJELL (%)	T-TEST (PAR)
10 GRAM	229	.37	30.9	.005
20 GRAM	175	.28		(26)
10 GRAM	214	.38	116.2	0.000
30 GRAM	99	.18		(23)
20 GRAM	213	.28	73.2	0.000
30 GRAM	123	.17		(30)

Table 2.3.14. Catch data from Trial 64,hook no.4.

AGNPAR	ANTALL HYSER	FISK PR KROK	FORSKJELL (%)	T-TEST (PAR)
10 GRAM	304	.47	53.5	0.000
20 GRAM	198	.31		(27)
10 GRAM	276	.47	160.4	0.000
30 GRAM	106	.18		(24)
20 GRAM	244	.30	75.5	0.000
30 GRAM	139	.17		(34)



Bait size	10	20	30
Nos.measured	407	389	231
Mean length	41.6	42.1	42.8
+/-95% KONF.	.49	.51	.69
KRUSK.-WALL.	.032		
MANN-WHITNEY	*	*	.147
(* markerer	*	.011	*
testvariab.)	.186	*	*

Figure 2.3.8. Length data from Trial 64.

there are only small differences in the selective properties.(p.49)

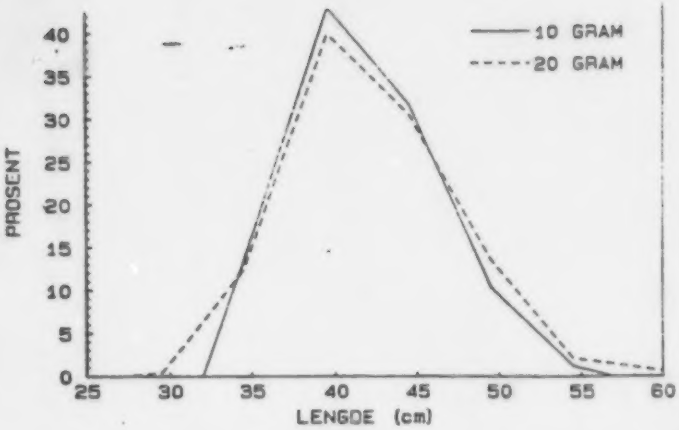
If we compare the results in the three experimental series, only Trial 65 stands out in that in this series there were no differences in the catching power of 10 g and 20 g baits. This is probably due to the fact that haddock were unevenly distributed in this period and that the data material was quite small. However, seen in total the results are still quite unambiguous. It seems to be clear that there are only small selectivity differences between 10, 20 and 30 g baits, while small baits are considerably more effective than small baits.

Hook - vs - hook comparison of 10 and 20 g baits.

This trial was carried out in about the same period as Trial 64. The catch consisted almost exclusively of haddock, and it is therefore only this species that is being discussed. The experiment was designed to compare 10 and 20 g baits in alternating positions along the line; a so-called hook-vs-hook comparison. The reasoning behind doing this experiment was to compare this experimental setup with paired comparison of cells with bait.

In order for the processing of the results should be as much as possible in line with the other trials, the catch was summed over 50 hooks and then subjected to a t-test for paired comparisons. Similar to the preceding experimental series, the catch rates were calculated on the basis of catch and registered hooks in acceptable pairs. The pairs were rejected if they were without fish.

Catch - and length results are presented in Fig. 2.3.9. The catch differential was 31.4 percent in favour of 10 g baits, while the corresponding difference in trial 64 with hook no.6, which was the most likely to compare it with, was 30.9 percent. Similar to Trial 64, there was also here a slight tendency for 20 g baits to catch more haddock than 10 g baits. On the basis of these results it can therefore appear as if hook-vs-hook comparison and paired



Bait size	10	20
Nos.haddock	506	385
Fish per hook	.46	.35
Difference(%)	31.4	
T-Test (pair)	0.000	(46)
Nos.measured	431	242
Mean length	41.1	41.7
+/-95% conf.	.40	.62
Mann-Whitney	.253	

Figure 2.3.9. Catch-and length data from hook-vs-hook comparison of 10 and 20 g baits.

Table 2.3.15. Biological samples of haddock. The measurements are given with mean value +/-95% confidence interval.

Nos.	Length (cm)	Weight (kg)	Liver (g)	Condition factor
77	43.8+/-1.4	0.96 +/-0.09	44.9 +/-7.0	1.076+/-.024

Table 2.3.16. Stomach fullness.

Degree of fullness	Nos.	Percent
Empty (1)	27	34
Rest (2)	33	42
Half full (3)	13	17
Full (4)	2	2
Bulging (5)	4	5
Inside out (6)	0	0

Table 2.3.17.Stomach content

Content	No. of stomachs
Fish eggs	13
Fish rest	12
Ophiuroidea	10
Bottom substr.	10
Not ident.	8
Krill	4
Polychaeta	4
Hermit crab	2
Bait	2

comparison of cells give approximately the same result. In the concluding discussion on the various experimental setups this will be further discussed.

Saturation.

Since there were only marginal differences in the selective properties of 10, 20 and 30 g baits, any saturation could hardly have had any influence on the results. On the other hand, it could have led to the catch differences having been somewhat underestimated. However, it is not possible to establish if saturation did occur.

Biological samples.

Most of this material was collected during Trial 64. It is too thin to make a thorough analysis of. All data have therefore been combined , and they have been presented in the tables on the preceding page. Most of the haddock had little or nothing in their stomachs. Where there was stomach content, bottom organisms dominated. Otherwise it was interesting to note that two of the haddocks had bait in their stomachs: One had eaten five 20 g baits, while the other had eaten two 30 g baits. For comparison it should be noted that not a single cod stomach had a content that could be identified as bait.

Hook fastening point.

The hook fastening point for haddock is presented in Table 2.3.18. Only the results from Trial 64 and the hook-vs-hook comparisons of 10 and 20 g baits have been included. The reason for the data from Trial 65 and Trial 67 have been left out is that

Tabell 2.3.18. Krokfestepunkt - hyse.

—Table 2.3.18. Hook fastening point - haddock.

A

Bait (g (gram))	Hook no.	Hook fastening point						Registered hooks.
		Mouth		Swallowed		Body		
		Nos.	%	Nos.	%	Nos.	%	
10	6	221	96	0	0	10	4	674
	4	289	95	1	0	14	5	672
20	6	195	82	1	0	41	18	841
	4	240	90	1	0	27	10	830
30	6	108	80	1	0	26	20	829
	4	137	90	0	0	16	10	818
10	6	478	93	0	0	28	7	1102
20	6	320	83	3	1	62	16	1105

almost all the haddock in these experimental series were hooked in the mouth. The results from these series are otherwise presented in Table 2.2.3 under the hook studies.

Also in Trial 64 and in the hook-vs-hook comparison of 10 and 20 g baits were most of the haddock hooked in the mouth. But in addition there were also a considerable number of body-hooked fish, probably due to the high concentrations of haddock during these fishing trials. From Table 2.3.18 it can be seen that, in all the comparisons, the catch of body-hooked haddock was higher on 20 g baits than on 10 g baits ($p<0.001$, the binomial test; in Trial 64 the probability was calculated on the basis of the summed catches on hooks nos. 4 and 6). On the other hand, there was about the same ratio between mouth-hooked and body-hooked haddock on 20 and 30 g baits.

Fish that were hooked outside the mouth were likely caught as a result of other fish dragging or jerking the line ("poled" lines are very flexible due to the fact that they are floating up from the bottom). There seems to have been three possible factors that could have contributed to the variation in the catch of body-hooked haddock on the three bait sizes: (1) The number of "available" hooks, (2) different hooking probability or (3) different behaviour of the haddock towards the individual bait sizes.

(1) It is obvious that the number of free or available hooks will influence the number of body-hooked fish since with no free hooks there would be zero catch. There are, however, strong indications that other factors were of greater importance. For example, the catch of body-hooked haddock was considerably greater on hook no.4 with 20 g bait than on hook no.6 with 10 g bait ($p=0.024$, the binomial test), in spite of the fact that there was almost no difference in the number of free hooks on the two combinations (See Fig.2.2.17 and Fig.2.2.18). Furthermore, this explanation is not applicable in the comparisons between 20 and 30 g baits since there were more free hooks on 30 g baits, but still a higher catch of body-hooked haddock on 20g baits.

(2) The hooking probability could be thought to be (p.52) different as a result of the physical properties of the baits. There seems in this connection to be a reasonable assumption that the more of the point of the hook being exposed, the better the hook will be able to hook fast. Since the point of the hook is exposed more with 10 g bait, this hypothesis does not seem to be valid.

(3) Most of the body-hooked haddock were hooked in the head region. It therefore seems to be a reasonable assumption that it was fish that were interested in the bait, and not accidental "passers by". When there then were more body-hooked haddock on 20 g than on 10 g baits, it could possibly be due to that the haddock to a greater degree sniffed the 20 g baits, while the behaviour towards 10 g baits was more purposeful, for example in that they sucked the bait directly into the mouth. The low catch of both mouth-hooked and body-hooked haddock on 30 g baits can indicate that the haddock was little interested in a bait that large. Different behaviour towards the various bait sizes therefore seems to be the most likely explanation for the variations in body-hooked haddock.

Summary.

The results of the bait comparisons for haddock shows that there are only marginal differences in the selective properties of 10, 20 and 30 g baits. In contrast , there are considerable differences in the effectiveness. Similar to the cod data, there are two possible reasons for small baits being more effective than large, namely that the hooking probability is greater as a result of physical properties of the baits, or that more fish attack small baits than large. The results of the hook fastening studies indicate that fewer fish attack large baits than small, but outside this the results do not give any basis for drawing any definite conclusions.

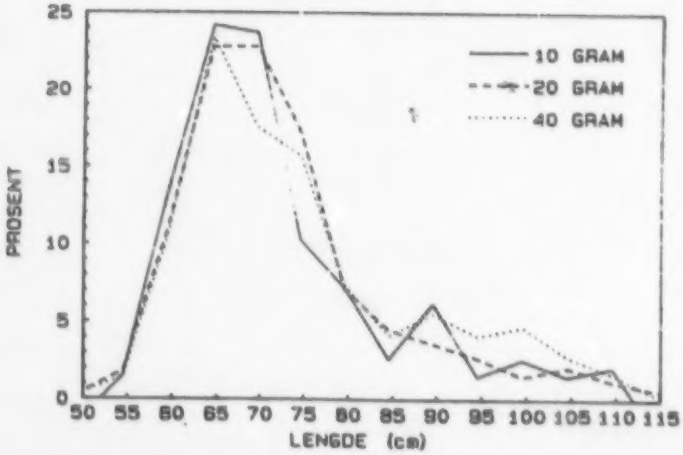
Table 2.3.19. Catch data from Trial 65,hook no.6.

Bait pair	No.of cod	Fish per hook	Diff. %	T-Test (pair)
10 GRAM	85	.21	11.8	.320
20 GRAM	95	.23		(14)
10 GRAM	74	.21	28.4	.053
40 GRAM	95	.26		(12)
20 GRAM	135	.18	23.7	.018
40 GRAM	167	.22		(28)

Table 2.3.20. Catch data from Trial 65, hook no.5.

AGNPAR	ANTALL TORSK	FISK PR KROK	FORSKJELL (%)	T-TEST (PAR)
10 GRAM	89	.22	37.1	.005
20 GRAM	122	.29		(14)
10 GRAM	78	.22	23.1	.056
40 GRAM	96	.28		(12)
20 GRAM	183	.21	3.1	.740
40 GRAM	188	.22		(28)

(See p.80)



AGNSTØRRELSE	10	20	40
ANTALL MÅLT	194	337	383
MIDDELLENGDE	71.1	72.1	74.1
+/-95% KONF.	1.87	1.32	1.41
KRUSK.-WALL.	.045		
MANN-WHITNEY	*	*	.216
(* markerer	*	.017	*
testvariab.)	.133	*	*

Figure 2.3.10. Length data from Trial 65.

2.3.3 The Gryllefjord trials.

Trial 65.

The material used as basis for the comparisons with 10 g baits were collected in two settings, while an extra setting was made for the 20 g and 40 g baits. The catch rates for the extra setting was considerably lower than for the two others,but the size of the fish was about the same. All length measurements are therefore included in the analysis of the length distributions, while the catch data as usual is based on paired comparisons.

The catch results for hooks nos. 6 and 5 are presented in respectively Table 2.3.19 and Table 2.3.20. In the comparisons with 10 g baits the experimental data were a little on the light side with only 14 pairs between 10 and 20 g baits and 12 pairs between 10 and 40 g baits. However, the 10 g baits had the lowest catches in all comparisons. The 40 g baits had significantly higher catches than the 20 g baits with hook no.6, while there were practically no differences in catches between the two bait sizes on hook no.5.

The length data on the hooks being compared is presented in Fig.2.3.10. Similar to the Vardö trials there was also here a tendency for the mean length of the fish to increase with the bait size: Between 10 and 20 g baits there was a difference of 1.0 cm and between 20 and 40 g baits it was 2 cm. It was, however, only between 10 and 40 g baits that the difference was significant. Otherwise it can be seen from the figure that the relative length distribution curves almost completely fall together over the whole length spectrum with the exception of the very largest fish where there is a tendency for the 40 g curve to lie somewhat above the others.

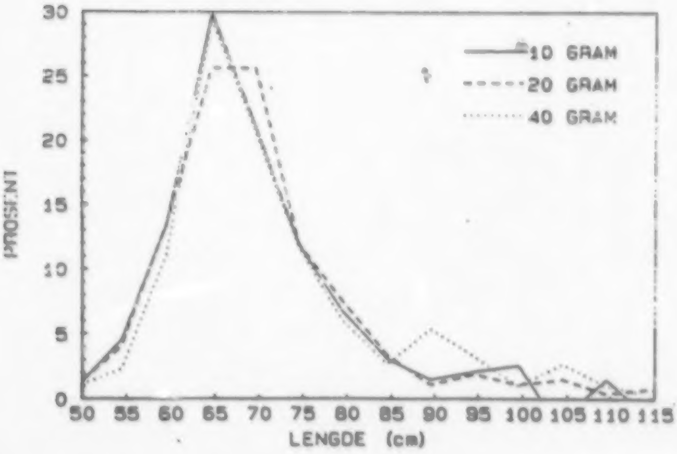
The results therefore indicate that there is a difference in the selective properties of 10, 20 and 40 g baits, but seen on a background of the large spread in lengths in the catch, the (p.54) differences seem to be relatively small. With the respect to the

Table 2.3.21. Catch data from Trial 67,hook no.6.

AGNPAR	ANTALL TORSK	FISK PR KROK	FORSKJELL (%)	T-TEST (PAR)
10 GRAM	62	.11	33.9	.028
20 GRAM	83	.15		(19)
10 GRAM	60	.12	66.7	.007
40 GRAM	100	.19		(16)
20 GRAM	103	.15	11.7	.364
40 GRAM	115	.17		(24)

Table 2.3.22. Catch data from Trial 67, hook no.7.

AGNPAR	ANTALL TORSK	FISK PR KROK	FORSKJELL (%)	T-TEST (PAR)
10 GRAM	49	.09	53.1	.003
20 GRAM	75	.14		(19)
10 GRAM	44	.09	61.4	.007
40 GRAM	71	.14		(18)
20 GRAM	89	.12	18.7	.330
40 GRAM	75	.10		(25)



(See p. 80)

AGNSTØRRELSE	10	20	40
ANTALL MÅLT	194	266	299
MIDDELLENGDE	68.8	69.6	71.1
+/-95% KONF.	1.59	1.36	1.43
KRUSK.-WALL.		.176 [1]	
MANN-WHITNEY	*	*	.396
(* markerer	*	.063	*
testvariab.)	.300	*	*

[1] IKKE GRUNNLAG FOR PARVIS TESTING

Figure 2.3.11. Length data from Trial 67.

differences in effectivity, these must be seen in connection with the hook size. It seems to be obvious that 10 g baits are less effective than 20 and 40 g baits. The effectivity of 20 g baits with hook no.5 and 40 g baits with hooks nos. 5 and 6 is on the other hand about the same , while the combination of 20 g bait and hook no.6 seems to be less effective. In other words, this means that by using hook no.5 the bait size could be reduced by half without loss of catch relative to the standard hook and bait (hook no.6 and 40 g bait).

Trial 67.

The length data on the hooks being compared have been combined also in this ex[erimental series. The catch data presented in Table 2.3.21 and Table 2.3.22, have, however, been processed separate for each hook. The catch on 10 g baits was in all comparisons significantly less than on the other bait sizes. On the other hand, there were no statistically significant differences in the catches on 20 and 40 g baits. In total the catch on 20 g baits was 192 cod compared to 190 on 40 g baits.

The length results are presented in Fig. 2.3.11. Like in the preceding series, there was also here a tendency for the mean length to increase with the bait size. The differences were small, however, and they were not significant either. From the figure it can otherwise be seen that the relative length distributions are close together over the whole length spectrum. The results therefore indicate that there are only small differences in the selective properties of 10, 20 and 40 g baits.

The results of this and the preceding series show that 10 g baits are less effective than the other bait sizes in the Gryllefjord area, while the effectiveness of 20 and 40 g baits are approximately the same. Furthermore, the bait size seems only to a small degree to have an influence on the selectivity. (p.55)

Table 2.3.23. Biological samples of cod. The measurements are given as mean value +/-95% confidence interval.

Ant.	Lengde (cm)	Vekt (kg)	Lever (g)	Kondisjonsf.
68	72.5 +/-3.3	4.02 +/-.714	224.0 +/-66.6	.929 +/-.021

Table 2.3.24. Stomach fullness.

Fyllingsgrad	Antall	Prosent
Tom (1)	53	78
Rest (2)	12	18
Halvfull (3)	2	3
Full (4)	0	0
Utspilt (5)	0	0
Vrengt (6)	1	1

Table 2.3.25. Stomach contents.

Innhold	Antall mager
Agn	8
Børstemakk	3
Krill	2
Reke	1
Slangestjerne	1
Akkar	1
Sild	1

Table 2.3.26. Hook fastening point - cod.

Agn (gram)	Krokfestepunkt			
	Munn		Slukt	
	Antall	Prosent	Antall	Prosent.
10	270	87	41	13
20	441	83	90	17
40	460	74	161	26

Biological samples.

The material collected during the last setting in Trial 65 is too thin to be subjected to thorough analyses. All data have therefore been combined and the results presented in the tables on the preceding page. Most of the 68 stomachs studied were without contents. However, it is interesting to note that 8 of the fish had bait in their stomachs: Five cod had eaten one mackerel bait each, two had eaten one squid bait while one cod had eaten two squid baits. The mackerel baits could have come from the hook on which the fish was caught (if the fish had swallowed the hook into the stomach the bait was not counted as stomach content). On the other hand, it seems to be obvious that the cod with squid bait in the stomach had attacked the line repeatedly. For comparison, during the analysis of twice as many cod stomachs in the Vardö trials not a single stomach containing bait was found. It could therefore appear as if the behaviour of the fish towards the line was different in the two periods.

Hook fastening point.

The result of the registration of the hook fastening point (hooking point) is presented in Table 2.3.26. By far most of the fish were hooked in the mouth, while some had swallowed the hook. The incidence of body-hooked fish was low, and this part of the catch has therefore not been included in the table (see Table 2.2.7 for the hook studies for more detailed results).

The ratio between the catch of mouth- hooked and hook-swallowed fish was about the same on 10 and 20 g baits ($p=0.175$, the Chi - square test). On the other hand, fish that had swallowed the bait comprised a considerably larger part of the catch on 40 g baits ($p<0.001$ in comparisons with both 10 and 20 g baits).
A possible explanation of this could be that the fish did not notice the hook in the long and narrow 40 g baits; in other (p.56)

words a physical property of the bait. But it could also mean that 40 g baits represents a stronger stimulus for swallowing than smaller baits.

Summary.

The results of the bait comparisons in the Gryllefjord fishing trials show that 20 and 40 g baits are about equally effective, while the effectivity of 10 g baits was somewhat lower. In spite of a large length spread in the catch (55 - 115 cm) and that there was a large variation in the bait sizes, there were only small differences in the selective properties of the baits tested.

2.4 BAIT STATUS - RESULTS AND DISCUSSION (p.57)

In recent years a number of studies of fish behaviour when facing hooks and baits have been done both in the laboratory and in the field. These studies have shown that fish of various species can bite on a hook several times without being hooked. This has therefore left an impression that the longline is not a very effective gear type, and work has to a large degree been aimed at improving the effectivity of the hook. It has , however, not been evaluated how realistic such studies are in relation to catches on "poled" lines. It can therefore not be discounted that the effectivity in a real fishing situation could be in part considerably higher than that shown in behaviour studies, and that the greatest potential for effectiveness is not connected with the hooking probability.

The chief objective of the bait status studies is therefore to illuminate the behaviour of the fish when facing the hook in a real fishing situation, and to evaluate the magnitude of the hooking probability. Otherwise, comparisons are made with the results of behaviour studies in order to evaluate the realism in such studies. Some observations from our own behaviour studies are also included in the evaluations. In all cases these are results that are not presented under the chapter on behaviour studies.

2.4.1 The influence of the fish on the bait status.

In order to be able to use the bait status to illustrate the behaviour of the fish towards the bait, it is necessary to know something about how much the fish contribute to the different bait status.

Table 2.4.1. Correlation analyses between relative share of the various bait status and catch rates. The Vardö trials.

Bait(g)	Trial No.	No. of points	Blank hooks		Half baits		Whole baits	
(g)		punkt	r	p	r	p	r	p
10	65	45	.204	.178	-.203	.182	-.226	.136
	67	45	.311	.037	-.225	.138	-.215	.156
	64	36	.496	.002	-.342	.041	-.562	.000
20	65	42	.480	.001	-.222	.159	-.320	.039
	67	39	.597	.000	-.451	.004	-.147	.372
	64	44	.032	.836	.418	.005	-.370	.014
30	65	42	.381	.012	.030	.850	-.251	.109
	67	41	.518	.000	-.239	.122	-.122	.475
	64	41	-.189	.236	.399	.010	-.234	.141

The Vardö trials. (p.58)

The number of blank hooks, half and whole baits on the various hook/bait combinations is presented in Table 2.4.4 further back in this paper. To study how much the fish contributed to the various bait status/conditions, the linear correlation between the catch rate in the cells and the relative part of the various bait status was calculated. The latter is given as the ratio between the number of hooks remaining without fish and the number of the actual bait status (for example, in a cell of 50 hooks with a catch of 20 fish (catch rate = 0.40) there will be 30 remaining hooks without fish, and if 15 of these are clean (blank) hooks, we obtain the point 0.4, 0.5). If the fish affect the bait status, it should be expected that where there are many fish, there would be relatively many blank hooks and/or half baits, while the opposite would be the case where there are few fish. Not all statistical assumptions in connection with the analysis have been met. This is discussed in Appendix A , together with a closer description of the method.

The result of the analysis is presented in Table 2.4.1. The table shows the correlation coefficient (r) between the catch rates and each of the three bait status conditions, the test result for r being different from zero and the number of points used as a basis for the calculations. The bait status/conditions of the comparative hooks were combined, since there were not significant differences between the hooks in any of the cases.

From the table it can be seen that with 10 g baits there was a positive correlation between catch rate and blank hooks, while in contrast there was a negative correlation for both half and whole baits. A test to see if the r's for clean hooks in the three experimental series were the same, did not give rejection (p=0.345), and collectively for the series r=0.330 (combining several r's have been described by ZAR (1974)). In Trial 65 and Trial 67 the results with 20 and 30 g baits were about the same as with 10 g baits, ie that there was a positive correlation between catch rate and blank hooks, while there was a negative or no

Table 2.4.2. Correlation analysis between relative share of the various bait conditions (status) and catch rate. The analysis is done on "pure" cod - and haddock cells. The Vardö trials.

Species	Bait (g)	Number point	Clean hooks r	Clean hooks p	Half baits r	Half baits p	Whole baits r	Whole baits p
Torsk	10	45	.368	.013	-.127	.405	-.436	.002
	20	46	.461	.001	-.129	.392	-.334	.023
	30	65	.325	.008	.071	.576	-.290	.019
Hyse	10	31	.288	.116	-.250	.175	-.306	.094
	20	33	-.019	.917	.302	.087	-.291	.010
	30	38	-.087	.604	.207	.213	-.171	.305

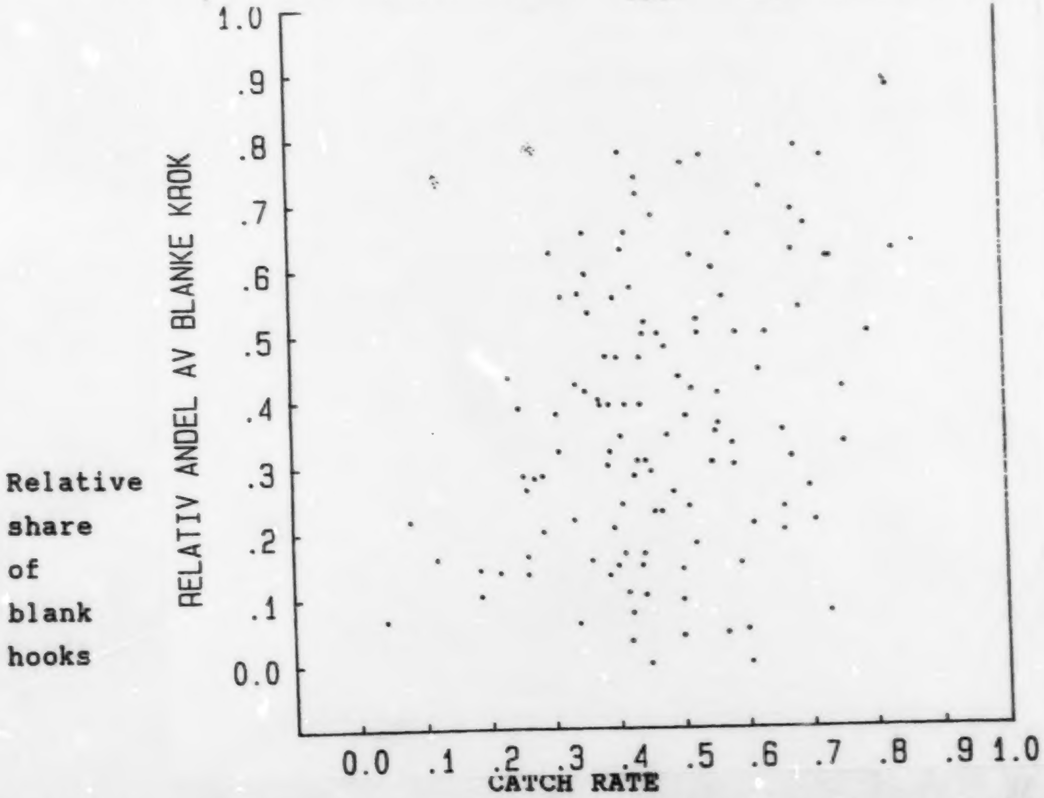
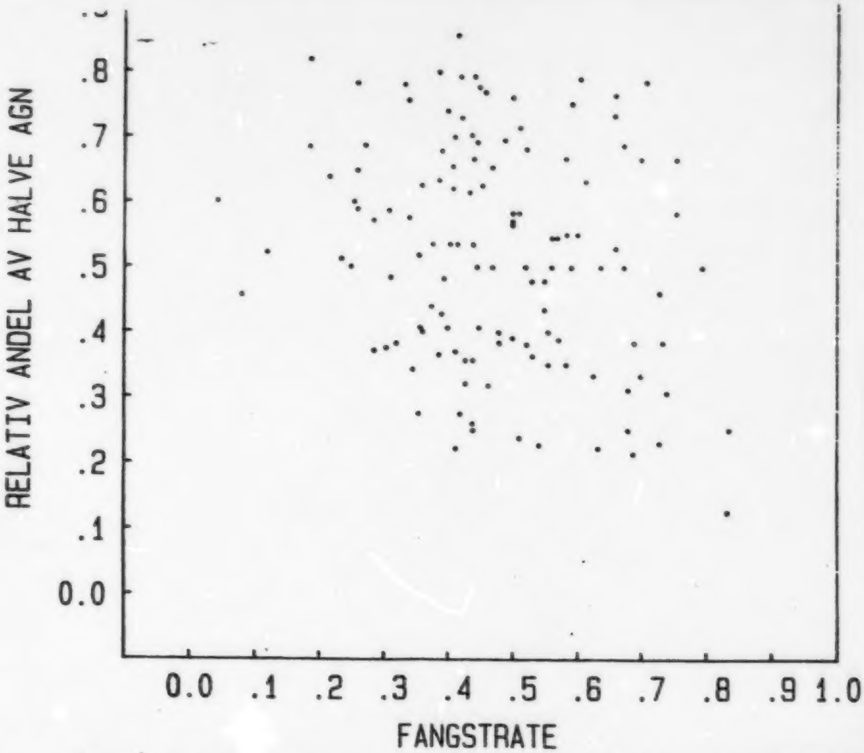


Figure 2.4.1. The relative share of blank hooks on 10 g baits in relation to catch rate (r=0.330, p<0.001). The Vardö trials.

correlation with the other hook conditions. However, in (p.59) Trial 64 the results were different. In this experimental series there was no connection between catch rate and blank hooks, while on the other hand there was a positive correlation between catch rate and half baits both with 20 and 30 g baits. Since there were considerably more haddock in Trial 64 than in the two other series, the differences can possibly be due to different behaviour of cod and haddock.

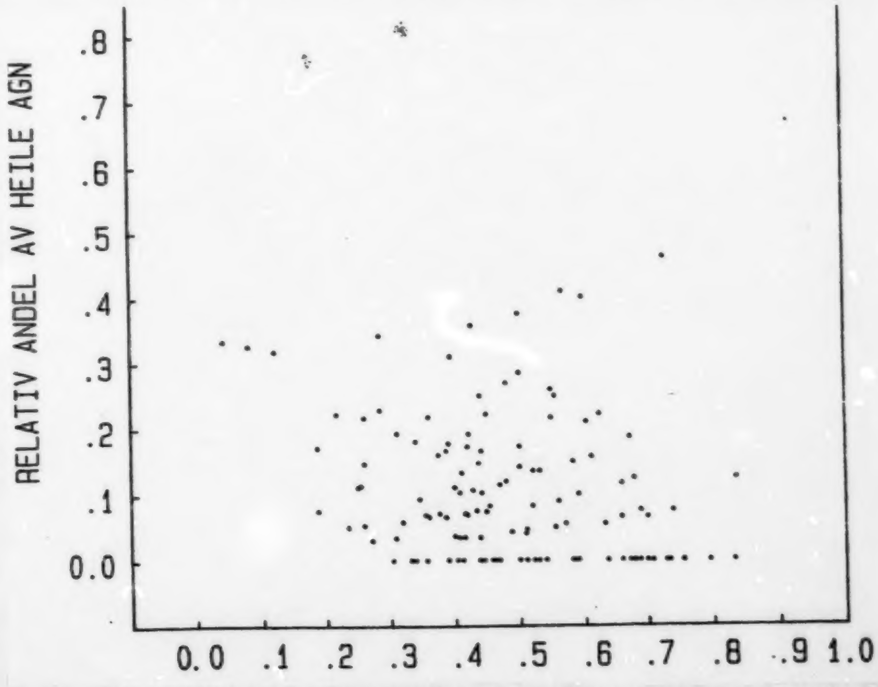
The behaviour of cod and haddock was studied by calculating corresponding correlations for "clean" cod and haddock cells. In these analyses the material from all experimental series was combined. Choice of cells were made according to the following criteria: Cells were rejected if the catch rate of species of no interest (non-target species) exceeded 0.10 (ie ca 5 fish) or the catch of these was larger than the catch of a target species (for example 2 of target species and 4 of non-target). The result of the analysis is presented in Table 2.4.2. For cod there was a positive correlation between catch rate and half and whole baits with all bait sizes. With respect to haddock, there was also here a positive correlation between catch rate and blank hooks with 10 g baits. With 20 and 30 g baits there was, however, a positive correlation between catch rate and half baits. The results therefore indicate that there is a difference in the behaviour of cod and haddock.

In Figs. 2.4.1, 2.4.2 and 2.4.3, the respectively relative shares of blank hooks, half baits and whole baits are plotted against catch rates. The data are from cells with 10 g baits and from all three experimental series. It can be seen from the figures that the variance was very high. Between blank hooks and catch rate there was a significant positive correlation of 0.330. The square of r, the so-called correlation index, shows how much of the variation of a variable can be explained by correlating the variable against another variable. In other words, it means that only about 11 percent of the relative share of blank hooks can be "assigned" to a variation in the catch rates. It is therefore(p.60)



Relative
share
of
half
baits

Figure 2.4.2. The relative share of half 10 g baits in relation to catch rate (r=0.-237, p=0.007). The Vardö trials.



Relative
share
of
whole
baits

Figure 2.4.3. The relative share of whole 10 g baits in relation to catch rate (r=-0.286, p=0.0001) The Vardö trials.

clear that an r of 0.330 shows that there is little connection between the variables.

From Figs. 2.4.2 and 2.4.3 it can be seen that it was a significant negative correlation between both half baits and catch rate and whole baits and catch rate. The reason for this negative connection is likely due to a dependence between the bait conditions: When the relative share of clean hooks increase, the share of hooks with baits (both half and whole) declines. A partial correlation analysis used on the total material for half 10 g baits, where the linear dependency to clean hooks was eliminated, also showed that it was about zero correlation between the relative share of half baits and catch rate. A corresponding analysis for the other bait sizes was not done, but there is reason to believe that the negative correlations also here are due dependence between the two bait conditions (status). The distribution of these bait sizes is not presented in a figure since they only deviated from the corresponding 10 g baits by having another centre of gravity.

The results of the correlation analyses therefore indicate that the fish affect the bait status only to a small degree. Because of these somewhat surprising results, two other analyses were done, and both of these yielded a result corresponding to the correlation analyses (the results of these analyses are presented in Appendix A).

Briefly summarized the results of the correlation analyses therefore indicate the following:

(1) Cod affected the number of blank hooks on both 10, 20 and 30 g baits, but did not contribute to half baits.

(2). Haddock affected the number of blank hooks on 10 g baits. On the other hand, on 20 and 30 g baits haddock affected half baits, but not clean (blank) hooks.

(3). The principal tendency is, however, that other factors than the fish were of much greater importance for the number of the various bait conditions.

Table 2.4.3. Correlation analyses between relative share of the various bait status and catch rate. The Gryllefjord trials.

Bait (g)	Trial	No. pts.	Blank hooks		Bait remnants		Half baits		Whole baits	
			r	p	r	p	r	p	r	p
)	65	14	-.108	.713	.026	.928	.288	.318	-.255	.379
	67	24	.291	.168	.578	.003	.457	.025	-.658	.000
)	65	29	.637	.000	.407	.028	.577	.001	-.720	.000
	67	28	.466	.013	.239	.220	.387	.042	-.586	.001
)	65	29	.493	.007	.328	.082	.610	.000	-.694	.000
	67	31	.758	.000	.742	.000	.124	.508	-.824	.000
d. drift		288	.329	.000	.238	.000	.272	.000	-.441	.000

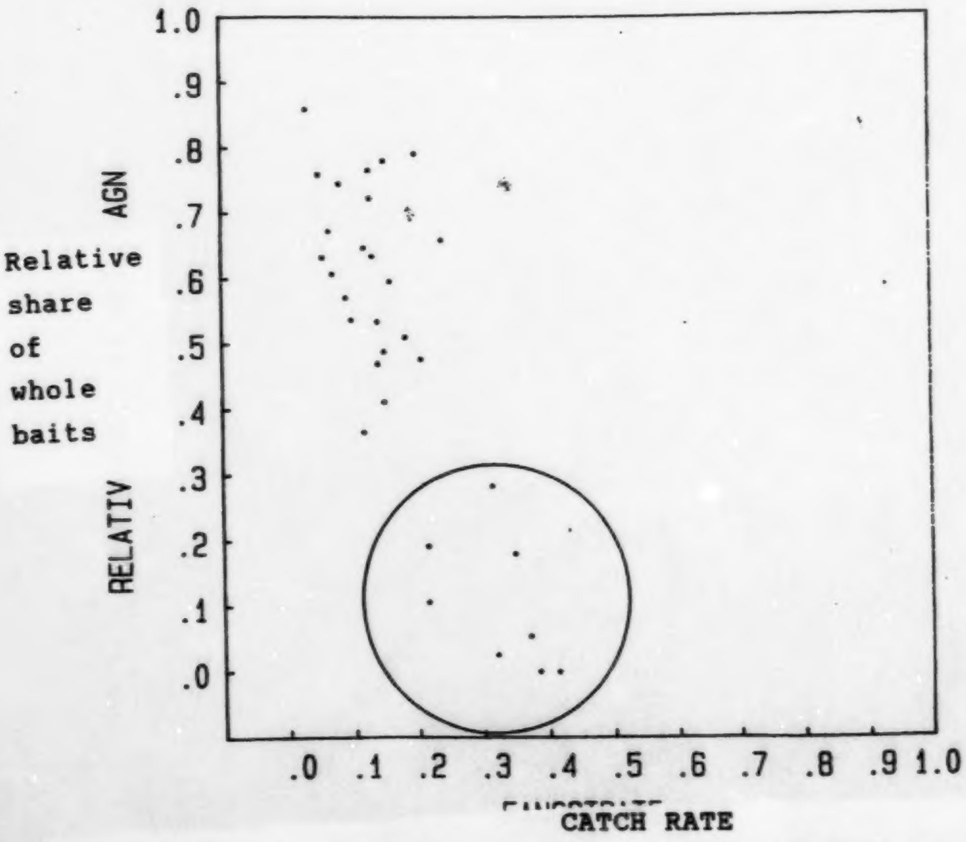


Figure 2.4.4. The relative share of whole 40 g baits vs catch rate, Trial 67. The circled part of the distribution is from one setting but the rest of the distribution is from other settings. The Gryllefjord Trials.

The Gryllefjord Trials.

(p.61)

In these correlation analyses (Table 2.4.3), in addition to the experimental fishing data, results from regular fishing operations in Gryllefjord have been included (Section 2.5). The number of different bait conditions is presented in Table 2.4.5 and Table 2.5.2 further back in this report.

In Fig. 2.4.4 the share of whole 40 g baits in Trial 67 is plotted against the catch rate. In this distribution there was an significant r of -0.824, which could indicate that the fish to a high degree had affected the bait condition (status). However, there is reason to question the magnitude of this connection. The circled part of the distribution is from one and the same setting. The soak time in this setting was four days with the rest of the distribution comprising one and two days soak times. Long soak times resulted in high catch rates also in Trial 65. If the settings with long soak times are kept out of the correlation analyses, there are not significant connections in any cases in the experimental fishery. It can therefore be imagined that the connection between fish density and the various bait conditions is partly due to the long soak times. The results that are presented in Table 2.4.3 are therefore very uncertain. (It can be mentioned that corresponding studies were also done with data in the Vardö trials without any similar results being found).

In the regular fishing operations there were significant positive correlations between catch rates and the different bait conditions. The exception was whole baits where there was a negative correlation. The material used for these analyses is very large and in addition from a number of settings. This result therefore shows that the fish contributed to both clean hooks, bait remnants and half baits. The relatively low r's indicate, however, that other factors were of much greater importance than the fish. The results from regular fishing operations cannot without reservation be transferred to the experimental fishery due to the fact that different bait types were used. However, there seems to be a reasonable assumption that the tough squid baits (used (p.62) in the regular fishery) would be able to resist more attacks than mackerel baits, so that the effect of cod on bait conditions was likely higher in the experimental fishery than in regular fishing operations.

On the basis of the correlation analyses and that over 10 percent of the fish studied had bait in their stomachs, it therefore seems to be clear that the fish contributed to the different bait conditions. However, it is not possible to determine how large the contribution was.

Discussion.

Due to the uncertainty in the Gryllefjord results the first part of the discussion will deal with the Vardö trials. The differences between the results in the two trial periods will be discussed later.

The number of baits that fall off a floating line has been studied by SHEPARD et al (1975). On longlines without fish the number of blank hooks varied from 6 to 836 per 1000 hooks with an average of 444. They concluded that the following factors had an influence on the loss of bait: wave height during hauling, vessel (vessel size and crew), soak time and year (likely as a result of variation in bait quality from year to year). They assumed that the baits fell off the hook as a result of movements of the line, and that most fell off during hauling since the baits are then softer and the movement of the line is often large as a result of the vessel rolling.

It could be imagined that movement in the line was an important reason for blank hooks also in these studies, and that the positive correlation with catch rates is therefore indirectly due to the fish because of the increased movement caused by hooked fish. (It is in this connection important to take into account that mackerel bait is almost weight neutral in seawater). There are several observations that point in the direction that this is a correct reflection. In the behaviour studies it was (p.63) observed that when cod or haddock bit on the hook without being hooked, it often led to wear and tear of the bait (half bait). In contrast, it seemed to be much rarer for the fish to steal the whole bait (blank hook), even if the barb on the hook had been filed off. Several results from the fishing trials indicate that also in an actual fishing situation is half a bait the most likely bait condition (status) if the fish is "grazing" on the baits. In the Vardö trials no baits were found in the stomachs of cod, while there were found 20 and 30 g baits in the stomachs of haddock. Correspondingly haddock affected half 20 and 30 g baits, but not blank hooks, while cod only contributed to blank hooks on the various bait sizes. On the other hand, in the Gryllefjord trial cod contributed to all bait status categories, and baits were also found in cod stomachs in this period. It is therefore not too likely that the fish should be able to affect blank hooks (direct effect) without at the same time affecting half baits. Otherwise the biological studies strengthen the impression that cod and haddock had different behaviour to hooks and baits in the Vardö trials. This will be discussed in connection with the behaviour studies.

The data do not give a basis for what could have caused half baits. One could speculate that it could for example be small fish of various kinds, other biological organisms (squid who is a known bait eater were not in the area), and some baits could have dissolved more or less in the seawater.

In addition to our own observations, others have also reported that when fish attack hooks and baits without being hooked it leads to wear and tear on the baits (SUTTERLIN, SOLEMDAL & TILSETH 1982, SOLEMDAL, TILSETH & BAKKEPLASS 1983). In the work on developing artificial baits it has also been an important working hypothesis that the bait must have physical strength to make it able to resist wear and tear, for example from repeated attacks by fish (SOLEMDAL et al 1983). It is therefore somewhat surprising that the fish in the Vardö trials did not seem to have affected the bait condition (status) to any great extent. This could possibly have two explanations: (1) The fish attacked the baits with such low intensity that it did not lead to substantial wear and tear, (p.64) (2) the hooking probability was very high, or a combination of 1 and 2. Both these explanations clash with the impression obtained by studying the behaviour of cod, haddock and whiting in facing hooks and baits (**FERNÖ** et al 1976, 1977, 1981, **FERNÖ** & **HUSE** 1983, **TILSETH**, **SOLEMDAL** & **FERNÖ** 1978, **HUSE** 1979a, **JOHNSTONE** & Hawkins 1981). In all such studies the hooking probability was quite low. Some of the highest observed for cod is 0.25 hookings per attack (**FERNÖ** & **HUSE** 1983), where an attack is defined by the fish sucking in the bait and then making an intensive movement. The major conclusions from such behaviour studies have therefore been that the hooking probability is low, and that it is almost exclusively intensive behaviour patterns that leads to hooking. This combination will, however, lead to wear and tear on the baits.

The reason for the differences between the behaviour studies and what was observed in the Vardö trials, is probably connected with the belief that the behaviour studies are not very realistic for a fishery with a "poled" line, in any case in the Vardö area. In behaviour studies it is usual to have a hook (sometimes several) hanging in front of a TV camera in an arrangement that is not very flexible. The hooking will therefore in its entirety depend on the distinctive activity of the fish. In a real fishing operation, several fish will usually attack the line and it is likely that often several fish will attack at the same time. A "poled" line is in addition very flexible, so that when a fish attacks hook and bait, it will often drag the line with it for some distance. if it is a big fish, the speed could probably be quite high. This leads to the other baits being set in motion. It is known that moving objects stimulate the feeding behaviour of the fish (**ARANOV** 1959, **BRAWN** 1969), and it is also movement that is the basis for all hook fishery without bait (jigging, trolling etc.). **BRAWN** (1969) has also observed that when a fish makes rapid and intensive swimming movements, it will stimulate the feeding behaviour of other cod. A fish that grabs a moving bait will probably swim in the opposite direction of the movement (flight reaction), so that the catching process will more resemble jigging or trolling. A fish can (p.65) even be hooked by another fish jerking the line. That this has occurred could be seen by the large number of body - hooked haddock. Activity of hooked fish can also be an important reason for hooking of fish in the mouth.

It is therefore reason to believe that the effectiveness in a real fishing situation will vary somewhat, for example as a result of one or several fish attacking the line at the same time. Since the fish do not seem to have affected the bait status to any large degree, it is not possible to use the bait status to establish the magnitude of the hooking probability. It is , however, reason to believe that if the effectivity had been low, it would have led to wear and tear on the baits.

At the same time it is obvious that the hooking probability could not have been 100 percent since there were observed effectivity differences between the various hook sizes. When the fish does not seem to have affected the bait status to any extent, there is reason to assume that the intensity in the attacks have been relatively moderate. Low intensity in the attacks also gives a reasonable explanation for the results of the hook studies in the Vardö trials in that the penetrating ability stood out as the most likely reason for the observed effectivity differences between the hooks.

The reason for the differences between the bait status analyses in the Vardö and Gryllefjord trials is probably due to different behaviour of the cod. The impression of different behaviour is also strengthened by the biological studies in that over 10 percent of the cod in Gryllefjord had bait in their stomachs , while no baits were found in cod stomachs in Vardö.It is also interesting that the penetrating ability of the hooks was of little importance for the effectivity in the Gryllefjord trials, something that could indicate that the cod attacked hooks and baits with relatively high intensity. High intensity in the attacks also gives a reasonable explanation of why the cod affected the bait status in Gryllefjord, but not in Vardö. Due to the uncertainty of the results, it is not possible to come to a decision on if (p.66) the hooking probability in the Gryllefjord area was high or low.

The results of the correlation analyses therefore indicate that the catch situation during behaviour studies is not very realistic for "poled" lines in the Vardö area. One should therefore be careful in generalizing from behaviour studies, and it seems to be clear that such studies can not be used as a basis for evaluating the effectivity of "poled" lines.

2.4.2 Bait status - the hook comparisons.

The Vardö trials.

The number of the various bait status and the catches on the different hooks are presented in Table 2.4.4. If a hook holds the bait less securely than another, there will be relatively more blank hooks and correspondingly less remaining bait on this hook, while the share of the different bait conditions will be the same on two types of hook that hold the bait equally well. The expectation values in the table are calculated on the basis that the various hooks hold the bait equally well, and this has been tested statistically with the help of a Chi - square test. It was found that there was only a significant difference between hook nos. 4 and 6 with 10 g baits. With the exception of this comparison, the shares of the different bait conditions (status) were nearly the same on the comparative hooks, something that means that the different hooks hold the baits equally well.

An interesting diversion from these results is that the (p.67) width of the barb does not seem to have any influence on how well the bait hangs on the hook, within the variations in barb width

Table 2.4.4. Bait status - hook comparisons.Vardö trials.

Bait (g)	Hook no.	Bait status						Catch	Reg. hooks	p
		Clean hook		Half bait		Whole bait				
		Obs.	Exp.	Obs.	Exp.	Obs	Exp.			
(g)	nr	Blank krok		Halvt agn		Heilt agn			krok	
		Obs.	Forv.	Obs.	Forv.	Obs.	Forv.			
10	6	184	(178)	318	(317)	82	(90)	485	1069	.370
	5	137	(143)	254	(255)	80	(72)	587	1058	
20	6	144	(131)	336	(340)	131	(140)	377	988	.103
	5	94	(107)	283	(279)	125	(116)	473	975	
30	6	106	(104)	324	(325)	299	(300)	270	999	.957
	5	93	(95)	298	(297)	274	(273)	329	994	
10	6	213	(227)	287	(272)	56	(57)	487	1043	.189
	7	251	(237)	269	(284)	60	(59)	462	1042	
20	6	109	(110)	364	(364)	127	(126)	342	942	.987
	7	114	(113)	373	(373)	129	(130)	309	925	
30	6	108	(118)	388	(376)	239	(241)	287	1022	.278
	7	130	(120)	369	(381)	247	(245)	271	1017	
10	6	204	(168)	263	(289)	32	(42)	339	838	.000
	4	97	(133)	256	(230)	44	(37)	442	839	
20	6	149	(145)	454	(453)	79	(84)	376	1058	.670
	4	128	(132)	411	(412)	81	(76)	432	1052	
30	6	167	(154)	466	(477)	164	(166)	204	1001	0.224
	4	131	(144)	459	(448)	159	(156)	237	986	

found in the hooks tested.

In the comparison between hooks nos. 4 and 6 with 10 g baits, the number of clean hooks observed on hook no.4 was under-represented in proportion to the expectation value, while both half and whole baits were over-represented. This is probably related to a difference in baiting of the two hook types. In the most commonly used method, which is also considered to be the one that holds the bait best, the hook is forced twice through the skin of the mackerel bait (double baiting, see Fig. 2.1.5.). Many of the 10 g baits were, however, too small to be double baited with hook no.6, while it was possible with hook no.4 due to the small gap of this hook.

From the table it can be seen that there in all cases were fewest blank hooks on the comparison hook that gave the highest catch (see catch and number of observed blank hooks in the table). From this it follows that blank hooks probably mostly occurred after an active fishing period was over. If, for example, blank hooks arise before the fish starts to attack the line, there will be just as many blank hooks on the comparison hooks under the assumption that the hooks hold the bait equally well. This will furthermore lead to that the number of observed blank hooks on the most effective hook will be over-represented in relation to the expectation value. The more blank hooks that occur before the active fishing period is over, the more over-represented will blank hooks be on the hook that gives the highest catch. From the table it can be seen , however, that there was rather a tendency for the number of observed blank hooks on the hooks with the highest catch was somewhat under-represented in relation to the expectation value.

The bait status results therefore show that the different hooks hold the baits equally well, and that most of the blank hooks probably occurred after an active fishing period was over.

Table 2.4.5. Bait status - the hook comparisons.
The Gryllefjord trials.

Tabell 2.4.5. Agnstatus - kroksammenligningene. Gryllefjordforsøka.

Agn (g)	Krok nr	(See p. 108) Agnstatus								Fangst (alle arter)	p
		Blank krok		Agnrest		Halvt agn		Heilt agn			
		Obs.	Forv.	Obs.	Forv.	Obs.	Forv.	Obs.	Forv.		
10	6	49	(55)	19	(19)	82	(78)	156	(154)	98	.568
	5	60	(54)	19	(19)	71	(73)	147	(149)	110	
20	6	89	(94)	50	(50)	182	(177)	366	(367)	165	.882
	5	96	(91)	48	(48)	165	(170)	355	(354)	195	
40	6	111	(107)	44	(51)	179	(168)	288	(293)	191	.265
	5	104	(108)	58	(51)	159	(170)	308	(300)	191	
10	6	60	(65)	46	(45)	148	(154)	293	(283)	100	.583
	7	73	(68)	46	(47)	165	(159)	284	(294)	173	
20	6	101	(101)	63	(59)	119	(184)	379	(354)	132	.001
	7	105	(105)	57	(61)	184	(155)	344	(369)	114	
40	6	115	(129)	56	(61)	157	(157)	384	(365)	181	.113
	7	150	(136)	70	(65)	164	(164)	364	(383)	135	

The Gryllefjord trials. (p.68)

The results of the bait status analyses presented in Table 2.4.5, have been processed like those in the Vardö trials. There was generally good agreement between observed and expected values with respect to blank hooks. These results therefore support the conclusions from the Vardö trials that the different hooks held the baits well. The good correlation between observed and expected values of clean hooks points in the direction of that clean hooks also in this period occurred after an active fishing period was over. (From the table it can be seen that there were significant differences between hooks nos. 6 and 7 with 20 g baits, and that the difference was due to variations in the shares of whole and half baits. It is difficult to give a good explanation for the reason for this).

2.4.3 Bait status - the bait comparisons.

As blank hooks probably occurred mostly after an active fishing period was over, the ability of the different bait sizes to hang on the hook has probably not had any influence on the estimated catch differences in the bait comparisons.

(Text missing. Translators note)

Table 2.5.1 Regular fishing operations.

Catch Cod	Other sp.	No.of regstd. hooks	N	Length Mean	95% confid.
2278	57	15,799	320	72.0	+/-1.63

Tabell 2.5.2. Fordeling av fangst og agnstatus i forhold

Table 2.5.2. Distribution of catch and bait status relative to "pole" and floats. Pos.1 is closest to pole.

Pos.	Catch	Blank hooks	Bait remn.	Half bait	Whole bait
Pos.	Fangst	Blank krok	Agnrest	Halvt agn	Heilt agn
1	78	143	11	59	278
2	87	152	15	56	262
3	97	151	15	47	264
4	110	132	13	68	252
5	109	143	14	57	253
6	97	131	10	64	275
7	101	128	21	60	265
8	99	146	20	54	253
9	108	130	24	60	250
10	85	130	22	52	290
11	97	138	15	58	271
12	84	142	12	67	271
13	80	130	15	64	290
14	71	136	19	53	300
15	85	120	14	61	298
16	78	139	12	74	280
17	80	125	19	57	296
18	74	115	17	74	303
19	71	115	16	69	309
20	62	105	21	51	337
21	60	118	25	62	316
22	55	126	31	70	295
23	52	125	31	68	304

2.5 REGULAR FISHING OPERATIONS IN GRYLLEFJORD.

The chief objective of collecting data from the regular fishing operations that were carried out in parallel with the experimental fishery, was to study how the fish was distributed along the longline. It is important with such information in the choice of experimental arrangements for comparative fishing trials. In addition to the distribution of the fish, an analysis has also been done on how the bait status (condition) varies along the line.

Table 2.5.1 gives a summary of the catch- and length data and Table 2.5.2 presents the catch and various bait status relative to the poles and floats. Fig. 2.5.1 shows the catch in the different hook positions. It can be seen that the catch increased considerably from the hook closest to the pole to the hook in position 4. From here the catch declined steadily towards the float. Between the least and the most effective hook position there was a catch differential of over 150 percent. The reason for this catch distribution relative to pole and float is probably associated with the fish being more plentiful closer to the bottom. With respect to the relatively low effectiveness of the hooks closest to the pole, it could be imagined that the pole would scare the fish, or that the line is not very flexible near the pole which leads to less movement. However, it could also be that the most effective hook positions were found nearest to the bottom. In the behaviour studies it was observed that when cod attacked hook and bait, the attack was almost always directed downwards, and after being hooked, the cod would always remain under the line. If the behaviour is the same in the field, it could be thought that the fish pulled the line towards the bottom, and due to the buoyancy in the float in the pole, the line profile would be approximately like the catch distribution curve turned upside down. But regardless of what the reason was, the results indicate that the effectivity of the line under such conditions could be improved considerably by changing the setting method.

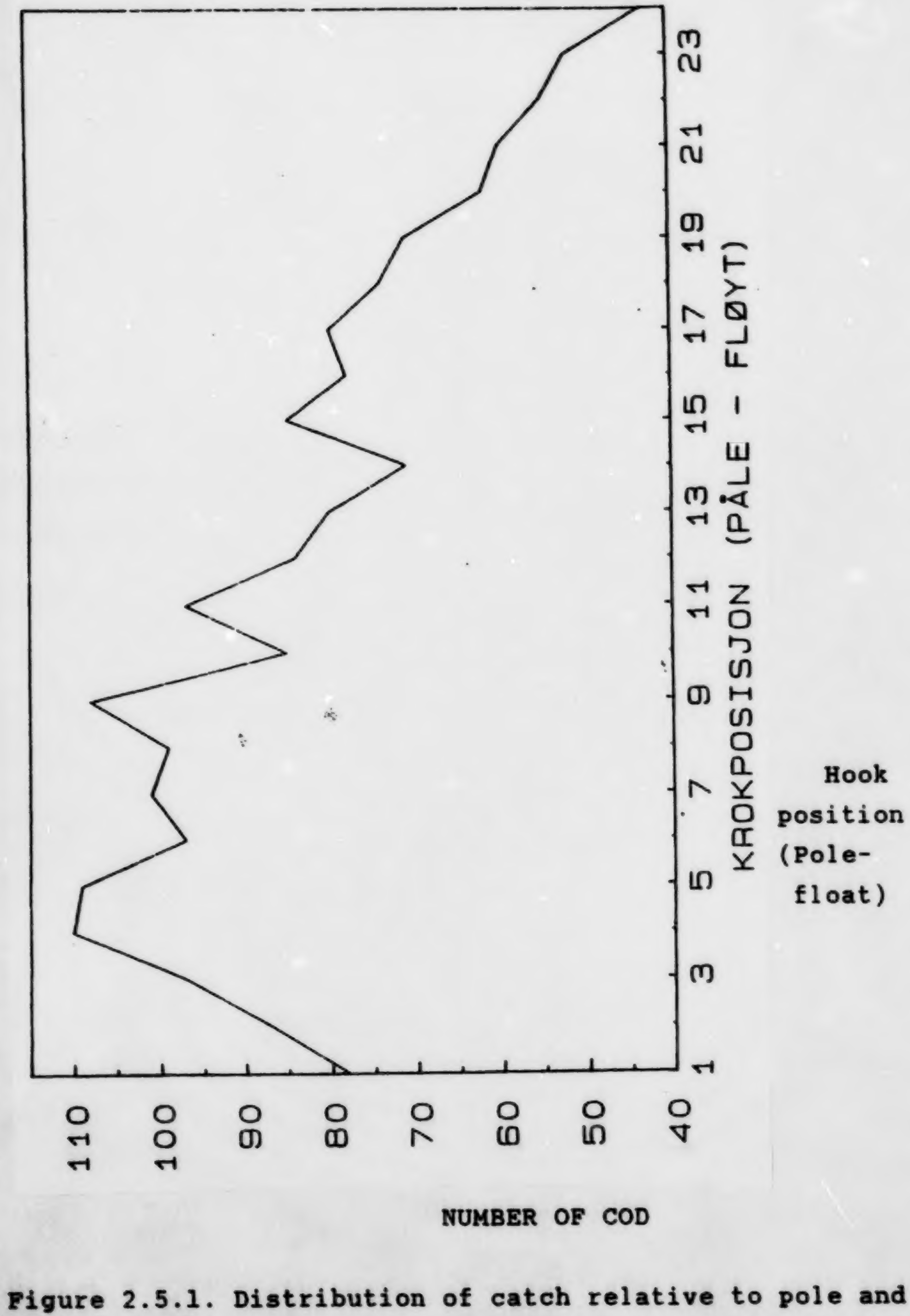


Figure 2.5.1. Distribution of catch relative to pole and float. Position 1 is the hook closest to the pole, and position 24 closest to the float.

The number of "vacant" hooks increased in step with the decrease in the catch upwards towards the float. The coefficient of climb (slope) (a) was estimated to be 2.40 ($p<0.001$, t-test) (p.70) with the help of a linear regression between the number of hooks without catch and hook positions. The results of the correlation analyses showed that other factors had a much greater effect on the bait conditions (status) than the fish during regular fishing operations. It should therefore be expected that the number of the different bait conditions would increase at the same rate as "vacant" hooks up towards the float under the assumption that the influence on the bait conditions was the same in the different hook positions. The number of bait remnants ($a=0.53$, $p=0.001$) and half baits ($a=0.48$, $p=0.025$) did actually increase up towards the float, while, on the contrary, the number of clean hooks decreased ($a=-1.19$, $p<0.001$). The results therefore indicate that there were different reasons for blank hooks and the categories bait remnants and half baits, and that the factors causing blank hooks had a stronger effect closer to the bottom.

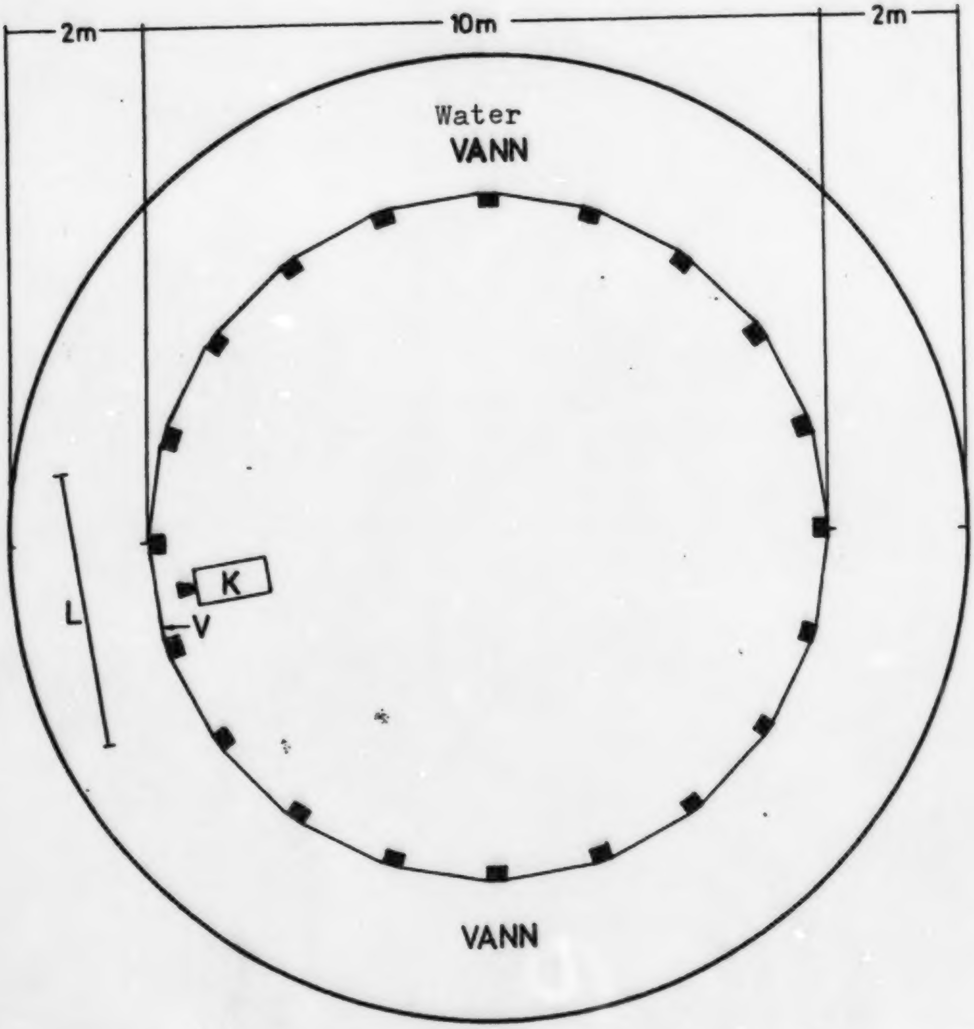

2m
10m
2m
Water
VANN
L
K
V
VANN

Figure 3.1.1. The round tank at the Institute of Marine Research,Bergen. L) line, V) observation window, K) video camera.

3 BEHAVIOUR STUDIES

(p.71)

The objective of these studies was to elucidate if the bait size affects the behaviour of cod and haddock, and if this possibly could be the reason for the observed differences in effectivity between small and large baits. Since the cod that were used in the behaviour studies was about the same size as in the Vardö area, and that the behaviour studies in conformity with the Vardö trials were carried out outside the spawning season, comparisons with the practical fishing trials will always be related to this trial period. The same also applies to haddock, in spite of that the haddock in the behaviour studies were somewhat larger than in the Vardö area.

3.1 MATERIALS AND METHODS

3.1.1 Experimental setup.

Behaviour studies were carried out in two periods: In November 1980 with cod as the experimental animal, and in May/June 1981 with haddock. The studies were carried out in the 125 cubic metres round tank at the Institute of Marine Research in Bergen (Fig. 3.1.1). A four metre long longline was mounted in front one of the windows in the round tank in an arrangement sketched in Fig. 3.1.2. Some actual dimensions are also shown in the figures.

The studies were designed to compare the behaviour of the fish towards 10 and 30 g mackerel baits. The baits were cut according to the average measurements in the Vardö trials (see Table 2.1.3 regarding dimensions). The two bait sizes were alternately fastened to the line on Mustad hooks no.5 without barbs, and the fish behaviour towards hook and bait was recorded on video tape. The starting bait size was varied from day to day. Each trial lasted for 10 minutes or until a fish was hooked. Hooked fish was carefully taken off the hook and released in the tank again. Four trials were usually made per day, but some days the response was so low that only two were made. There was a five minute pause between each trial. The trials were carried out in the middle of the day. The temperature of the water was in both trial periods about 8^0C. The fish were kept in artificial light left on 24 hours a day.

3.1.2 Trials with cod.

Twenty-one days before the start of the trial, 26 live cod were released in the round tank for acclimatization. The fish had been purchased from Bergen Fiskeindustri and had probably been caught in traps or gillnets in Nordmöre County. The mean length was 55.5 cm (46 - 72). The fish were not systematically fed neither during the acclimatization period nor in the trial period. To see how many had started to take food, a test feeding with mackerel was done. About half the fish had started to feed at the beginning of the experiments. A total of 17 experiments with each bait size was carried out over a period of 13 days. One fish died during the trial period.

3.1.3 Trials with haddock.

In this experiment a total of 30 haddock with a mean length of 55.1 cm (46 - 61) was used. The haddock were caught in a shore seine in Skogsvågen on Sotra three days before they were released in the tank. Most of the haddock were in excellent shape and practically without injuries. They also acclimatized quickly and many of them fed only two days after being released in the tank. Some of the haddock even ate out of our hands a few days later. After this they were not fed any more for 14 days. Most of them were then taking food. After 16 days acclimatization the experiment was started. Over a period of 24 days, a total of 20 experiments with each bait size was carried out. Five haddock died in the trial period.

(First line missing. Transl. note) p.73

the experiments. The behaviour of the cod will not be assessed because they were very shy and poorly acclimatized. However, some interesting differences in the behaviour of cod and haddock will be discussed.

3.1.4 Behaviour categories.

The behaviour of a fish, from the time it showed an interest for the bait and until it was hooked, swam away or was interrupted by another fish, comprised a behaviour sequence. The behaviour was described with the help of the following behaviour categories:

Approach (T) - the fish swims with purpose towards the bait, but swims away before getting there.

Sniff (Sn) - the fish touches the bait with the lips or barbels. If the fish does not swim away afterwards, it must take at least two seconds from the time the fish starts to sniff to the next action if it is to be counted as a sniff.

Sucked in (I) - the fish sucks the bait into the mouth, and the mouth is then closed.

Partly sucked in (Id) - the fish sucks in the bait without closing the mouth.

Bite over the bait (Ib) - the fish sucks the bait partly into the mouth and then bites over it.

Jerk (R) - the fish makes a jerky motion with high intensity.

Weak jerk (Rs) - the fish makes a not highly motivated jerking motion, distinguished from Jerk (R) by the lower intensity.

Spurt (Sp) - the fish swims with great speed and high (p.74) intensity.

Pulling (D) - the fish swims calmly away with the bait in the mouth.

Chewing (Ty) - the fish is calmly "chewing" the bait.

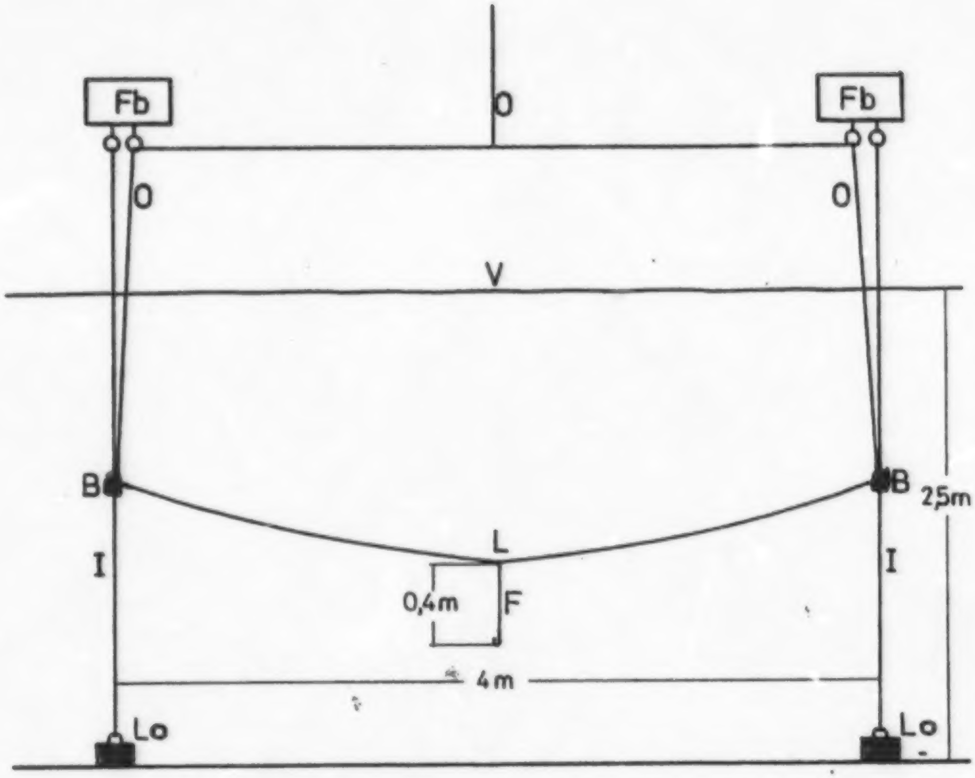
Spitting out (Ut) - the fish spits out the bait. This category usually concludes a behaviour sequence, but it can also be followed by for example a new "sucking in".

Hooked (K) - to be counted as being hooked the fish must hang on the hook for at least 20 seconds.

The behaviour sequences were divided into three phases: The introductory phase that consists of the categories approach, sniff and the different variations of sucking, the attack phase that consists of jerk, weak jerk, spurt, chewing and pulling, and the concluding phase consisting of spitting-out and hooking. This division of the behaviour does not mean that all three phases necessarily are included in all the behaviour sequences. For example, a sequence can consist of only an approach, or a sucking-in can be followed by a spitting-out.

When the behaviour is described as intensive, it implies high intensity in the movements of the fish. The categories jerk and spurt constitutes the intensive behaviour patterns.

Approximately corresponding behaviour categories have been used by FERNÖ *et al* 1977, TILSETH *et al* 1978, HUSE (1979a) and FERNÖ & HUSE (1983).



Figur 3.1.2. Linearrangement under atferdstudiene. L) line, F) forsyn, Lo) lodd, I) festetau, Fb) festebjelke, O) opphalingstau, B) blylodd, V) vannflate.

Figure 3.1.2. Longline arrangement in the behaviour studies. L) line, F) gangion, Lo) weight, I) fastening rope, Fb) fastening beam, O) hauling rope, B) lead weight, V) water surface.

(Transl. note.First line missing. Est.text based on next table:
Table 3.2.1. Changeover between the different behaviour categories in the trials with 10 g baits for cod. First category horizontal, following category vertically.

	T	Sn	I	Id	Ib	Rs	R	Sp	D	Ty	U	F
Antall	102	61	46	54	8	57	67	13	3	7	103	7
T	0	0	0	0	0	0	0	0	0	0	0	0
Sn	0	2	0	0	0	0	0	0	0	0	1	0
I	0	0	0	0	0	0	0	0	0	0	4	0
Id	0	3	0	0	0	0	0	0	0	0	11	0
Ib	0	0	0	0	0	0	0	0	0	0	3	0
Rs	0	0	19	15	0	15	5	0	1	2	0	0
R	0	0	15	11	6	10	22	0	2	0	0	0
Sp	0	0	2	0	0	0	11	0	0	0	0	0
D	0	0	2	0	0	0	0	0	0	1	0	0
Ty	0	0	6	0	0	0	0	0	0	0	0	0
U	0	0	2	28	2	32	29	6	0	4	0	0
F	0	0	0	0	0	0	0	7	0	0	0	0

Table 3.2.2. Changeover between the different behaviour categories in the trials with 30 g baits with cod. First category horizontal, following category vertical.

	T	Sn	I	Id	Ib	Rs	R	Sp	D	Ty	U	F
Antall	87	59	38	28	14	43	74	16	5	2	75	5
T	0	0	0	0	0	0	0	0	0	0	0	0
Sn	0	1	0	0	0	0	0	0	0	0	1	0
I	0	1	0	0	0	0	0	0	0	0	1	0
Id	0	3	0	0	0	0	0	0	0	0	6	0
Ib	0	1	0	0	0	0	0	0	0	0	0	0
Rs	0	0	12	11	1	10	8	0	1	0	0	0
R	0	0	19	4	10	8	30	1	1	0	0	0
Sp	0	0	2	0	0	1	12	0	1	0	0	0
D	0	0	2	1	0	0	0	0	0	2	0	0
Ty	0	0	2	0	0	0	0	0	0	0	0	0
U	0	0	1	12	2	24	24	9	2	0	0	0
F	0	0	0	0	0	0	0	5	0	0	0	0

3.2 RESULTS AND DISCUSSION. (p.71)

Not all the fish showed any interest in the bait. Among those that showed interest, most made a number of attacks in the trial period. To evaluate the effect of learning, if any, the trial period was divided into four periods with approximately the same total frequency of the different behaviour categories in each period.

3.2.1 Behaviour studies of cod.

Results.

Tables 3.2.1 and 3.2.2 show the frequencies of the different behaviour categories and the changeovers between the categories for respectively 10 and 30 g baits. The method used to generate these tables can be illustrated with an example. The following behaviour frequency has been given: I - R - R - R - Sp - U. The transitions in this sequence consist of one jerk after sucking-in, two jerks after jerk, a spurt after jerk, and a spitting-out after spurt. The objective of the transition tables is to elucidate which behaviour patterns most often follow each other. In that way it can be decided which behaviour categories in the introductory phase that would lead to intensive behaviour patterns in the attack phase. There were a total of 102 approaches to the 10 g baits. Since an approach means that the fish swims towards the bait and then turns away before reaching it, no other behaviour can follow. Of 61 cases of sniffing, it only happened five times that the fish did not swim away afterwards. In three cases sniffing was followed by partly sucking-in, and in two cases by a new sniff. Of 46 sucking-ins, two was followed by spitting-out, while about half the fish spit out the bait after partial sucking-in. From the table it can be seen that all the hookings followed after spurt. (p.76)

Tabell 3.2.3. Antallet av de ulike atferdskategoriene i innledningsfasen i periode 1 - 4 i atferdstudiene med torsk.

Periode	Agn Bait	T		Sn		I		Id		Ib		p
		Nos. Ant.	% Pro.	Ant.	Pro.	Ant.	Pro.	Ant.	Pro.	Ant.	Pro.	
1	10	14	25	9	16	28	49	6	10	0	0	.002
	30	28	48	16	27	11	19	3	5	1	2	
2	10	27	40	12	18	5	7	24	35	0	0	.006
	30	17	28	14	23	16	27	11	18	2	3	
3	10	31	48	21	32	5	8	8	12	0	0	.908
	30	23	39	17	29	6	10	7	12	6	10	
4	10	30	37	19	23	8	10	16	20	8	10	.910
	30	19	40	12	25	5	10	7	15	5	10	

Table 3.2.3. The number of the different behaviour categories in the introductory phase in period 1 - 4 in the behaviour studies with cod.

However,it must be added here that almost all the spurts followed after jerks which is also an intensive behaviour pattern. Since it is not possible to decide the exact moment of hooking, this could just as easily have occurred during the jerk. The results for 30 g baits are about the same as for 10 g baits.

The results therefore indicate that the categories approach and sniff reflects inhibited behaviour in the fish,while partly sucking-in could be interpreted as if the fish is somewhat less inhibited. Complete sucking-in of the bait was most often followed by intensive attack and therefore likely represents the most motivated action of the fish in the introductory phase.

The results from the introductory phase in the four periods are presented in Table 3.2.3. The table shows the observed frequencies and the percentage shares they represent. To test if the relative frequency of the behaviour patterns were alike on the two baits, a Chi - square test was used. Since there were so few cases when the fish bit over the bait, this category has been kept outside the test. From the table it can be seen that there were significant differences in the behaviour of the cod towards 10 and 30 g baits in the first period. The difference consisted in that many more cod did a complete sucking-in of 10 g baits (p=0.003, the binomial test; the expectation is calculated on the basis of the total number of behaviour patterns in the pattern), while approaches occurred more often towards 30 g baits (p=0.045). Sucking-in (I+Id+Ib) in total comprised 59 percent of the behaviour categories towards 10 g baits against only 26 percent towards 30 g baits. It is therefore evident that the behaviour of the cod towards 30 g baits was considerably more inhibited.

In the second period there were also considerable differences in the behaviour of the cod towards 10 and 30 g baits. In this period there were, however, most complete sucking-ins (I) of 30 g baits (p=0.004), while partial sucking-ins were the most common towards 10 g baits. Therefore, what seems to have happened compared to the first period, is that the behaviour of the cod (p.77) towards 10 g baits was strongly inhibited and that the interest in

30 g baits increased considerably (p=0.042, the Chi - square test applied to the frequencies of the different behaviour categories to 30 g baits in the first and second periods).

In the third and fourth period the share of sucking-ins dropped considerably, and there was no difference in the behaviour of the cod towards the two bait sizes either. It can also be added that the number of behaviour patterns towards hook and bait declined considerably during the trials. This does not appear in the results since the groupings in different periods were not done according to time , but with the aim that the number of behaviour categories in the different periods would be as alike as possible.

In Table 3.2.4 the results from the attack phase are given. The processing of these data have been done as in the introductory phase. The categories pulling and chewing are not included in the statistical analysis. It can be seen that in no periods were there significant differences in the behaviour of the fish towards 10 g and 30 g baits. It should be added that the test results in periods 2,3 and 4 are somewhat doubtful due to the few observed spurts.However, the conclusions are still the same by leaving out the spurt results in the statistical analyses. Otherwise it can be seen from the table that there was not an unambiguous tendency with respect to changing the behaviour throughout the periods, with the exception of pulling and chewing which only occurred in the first period.

The results from the concluding phase are presented on the right hand side of Table 3.2.4. Seven cod were caught on 10 g baits and five on 30 g baits. These catches are too small to make it possible to say anything about the magnitude of the hooking probability with the two bait sizes.

Briefly summarized the results show that there was only a difference between the behaviour of the cod towards 10 and 30 g baits in the introductory phase. In the first period the (p.78) behaviour was more inhibited towards 30 g baits than 10 g baits, something that was expressed by a high frequency of approach and a low frequency of sucking-in of 30 g baits. In the second period

Tabell 3.2.4. Antallet av de ulike atferdskategoriene i angreps- og avslutningsfasen i periode 1 - 4 i aterdstudiene med torsk.

Periode	Agn (g)	Angrepsfase Attacking phase											Avslutn. Concludind phase	
		Rs		R		Sp		D		Ty		P	U	F
		Ant. Nos.	Pro. %	Ant.	Pro.	Ant.	Pro.	Ant.	Pro.	Ant.	Pro.			
1	10	22	31	29	41	9	13	3	4	7	10	.896	33	3
	30	9	26	15	43	4	11	5	14	2	6		15	0
2	10	13	52	10	40	2	8	0	0	0	0	.109	27	2
	30	14	27	30	59	7	14	0	0	0	0		26	3
3	10	5	29	11	65	1	6	0	0	0	0	.712	12	1
	30	8	23	13	54	3	13	0	0	0	0		17	2
4	10	17	49	17	49	1	3	0	0	0	0	.654	31	2
	30	12	40	16	53	2	7	0	0	0	0		17	0
Tot.	10	57	39	67	46	13	9	3	2	7	5	.278	103	7
	30	43	31	74	53	16	11	5	4	2	1		75	5

Table 3.2.4. The number of the different behaviour categories in the attack- and concluding phases in periods 1 - 4 in the behaviour studies with cod.

the interest for 30 g baits increased somewhat at the same time as behaviour modification started to apply to 10 g baits. In the third and fourth period there was little interest in both bait sizes.

Discussion.

It is not simple to evaluate how relevant these results are for the fishing trials in Vardö. In the first place, the conditions in a laboratory are very different from a normal fishing situation. For example, in the laboratory only one fish at a time would attack the motionless bait, while in the field several fish would usually attack the line, and a motionless bait would therefore be an exception rather than the rule. It is furthermore likely that when wild fish are transferred to a laboratory the behaviour will be affected. It is , however, not possible to say to what a degree or how this could occur.

Another problem is that the experimental fish were not from the Vardö area. It is therefore reason to believe that the prey animals have not been the same as for cod in Vardö. SOLEMDAL *et al* (1983) have reported that feeding qualitatively affects the nutritional preferences of the fish. It could therefore also be imagined that different prey animals affect the choice of food particle size for the fish. However, mackerel is not a common prey for cod in any area, and in addition, a bait hanging from a line is a very unnatural situation. Facing such an unusual "prey", it could therefore be imagined that the background experience of the fish would not be of such great importance.

It has been reported that fish of different species go through a latency period before they will attack new and unknown prey animals (BEUKEMA 1968, WARE 1971). An interesting result in this connection is that the behaviour of cod towards 30 g baits (p.79) in the beginning was very inhibited, but gradually the interest picked up considerably before inhibition started to apply again as a result of learning. Towards 10 g baits the progress was different, with a strong response to begin with, but followed by a rapid decline. A possible explanation for this could be that the latency period lasted longer for 30 g baits. These results otherwise indicate that the fish to a small degree only can transfer experience from one bait size to another.

Since the difference in the behaviour towards 10 and 30 g baits was to be found in the introductory phase, it is reasonable to assume that it was visually dependent. A serious objection to the behaviour studies could therefore have been that the light intensity during the fishing trials , which were carried out at over 150 metres depth, was considerably lower than during the behaviour studies (ordinary room illumination). The sight of fish has been studied by, among others, BLAXTER (1965, 1980) and NORTHMORE, VOLKMANN & YAGER (1978). ANTHONY (1977) has reported that cod can observe objects down to 10^{-5} lux if the contrast between the object and the surroundings is at least 10 percent. The light intensity in the Vardö area has been measured by HUSE (1979a) in the beginning of July. He found that at 150 m depth the light level varied from one lux in the middle of the day in sunshine to 10^{-3} in the middle of night in overcast weather. If it is assumed that the light absorption was approximately the same in June 1980 as when HUSE measured the light levels, there is reason to believe that the fish have been able to see the bait both day and night.

One method to make a decision on if behaviour differences in the laboratory are realistic for the real catching situation is to see if it agree with observations from fishing trials.

Due to the behaviour modifications it is reasonable to assume that the behaviour of the cod in the first period was most representative for the normal catch situation. (A number of other authors have also reported that fish of different species quickly learn to avoid hooks and sharp objects.(BEUKEMA, 1970a; (p.80) 1970b; HACKNEY & LINKOUS, 1978; HUSE, 1979a; FERNÖ & HUSE, 1983). The interest towards 30 g baits was in this period considerably lower than towards 10 g baits. This result directly supports the påfølgende loddrett.

	T	Sn	I	Id	Ib	Rs	R	Sp	D	Ty	U	F
Antall	39	34	54	13	17	25	37	55	7	8	69	16
T	0	0	0	0	0	0	0	0	0	0	0	0
Sn	0	3	0	0	0	0	0	0	0	0	1	0
I	0	0	0	0	0	0	0	0	0	0	0	0
Id	0	0	0	0	0	0	0	0	0	0	0	0
Ib	0	0	0	0	0	0	0	0	0	0	0	0
Rs	0	0	11	3	4	4	0	0	1	2	0	0
R	0	0	14	1	3	1	9	7	1	0	0	0
Sp	0	0	18	0	7	10	12	0	3	4	0	0
D	0	1	5	0	0	1	0	0	0	0	0	0
Ty	0	0	6	0	0	0	1	0	1	0	0	0
U	0	0	0	9	3	9	10	37	1	0	0	0
F	0	0	0	0	0	0	2	11	0	2	0	0

Table 3.2.5. Transition between the different behaviour categories in the trials with 10 g baits with haddock. First category horizontally, the following categories vertically.

Table 2.3.6. Transition between the different behaviour categories in the trials with 30 g baits with haddock. First category horizontally, the following categories vertically.

	T	Sn	I	Id	Ib	Rs	R	Sp	D	Ty	U	F
Antall	43	82	31	3	44	9	59	47	6	1	71	6
T	0	0	0	0	0	0	0	0	0	0	0	0
Sn	0	10	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0	0
Id	0	1	0	0	0	0	0	0	0	0	0	0
Ib	0	7	0	0	0	0	0	0	0	0	0	0
Rs	0	0	2	0	4	1	1	0	1	0	0	0
R	0	0	14	0	20	1	20	3	1	1	0	0
Sp	0	0	7	0	15	1	19	0	5	0	0	0
D	0	0	5	0	0	1	0	0	0	0	0	0
Ty	0	0	1	0	0	0	0	0	0	0	0	0
U	0	0	2	3	5	5	18	38	0	0	0	0
F	0	0	0	0	0	0	1	5	0	0	0	0

observed differences in effectiveness between small and large baits in the Vardö trials. The result also gives a reasonable explanation for the selectivity differences between the baits since it is known that fish select prey animals on the basis of body size (WINDELL 1978, WANKOWSKI 1979).

In total the results therefore indicate that the most important reason for the observed differences in efficiency between small and large baits in the Vardö trials was that more fish attacked small baits.

3.2.2 Behaviour studies of haddock.

Results.

The results for haddock have been processed as those for cod. In Table 3.2.5 and Table 3.2.6 the frequencies of the different behaviour categories and the links between categories for respectively 10 g and 30 g baits are given. Similar to those for cod, most of the sniffs were followed by the fish swimming away. Sucking-in was most often followed by intensive behaviour patterns (jerk and spurt), but some instances of weak jerks, pulls and chewing also occurred. Partly sucking-in occurred relatively seldom, and in most cases it led to spitting out. In contrast to cod, haddock often bit over the bait (Ib). This category was usually followed by jerks or spurt. The results therefore show that sucking-in and bites over the bait represent the transitions to intensive behaviour patterns, while sniffing is assumed to reflect inhibited behaviour. Most of the cases of approach (p.81) were due to the fact that the haddock were disturbed by other fish that attacked the bait. This category therefore probably does not represent inhibited behaviour to the same extent as for cod.

In Table 3.2.7 the results from the introductory phase are presented. From the table it can be seen that it was only significant differences in the behaviour towards 10 g and 30 g

Tabell 3.2.7. Antallet av de ulike atferdskategoriene i innledningsfasen i periode 1 - 4 i atferdstudiene med hyse.

Periode	Agn Bait	T		Sn		I		Id		Ib		P
		Nos. Ant.	% Pro.	Ant.	Pro.	Ant.	Pro.	Ant.	Pro.	Ant.	Pro.	
1	10	7	19	8	22	16	43	2	5	4	11	.099
	30	6	13	17	35	12	25	1	2	12	25	
2	10	11	24	13	29	14	31	3	7	4	9	.215
	30	11	27	17	41	5	12	1	2	7	17	
3	10	13	33	7	18	8	21	8	21	3	8	.346
	30	17	33	16	31	5	10	1	2	12	24	
4	10	8	22	6	17	16	44	0	0	6	17	.001
	30	9	14	32	51	9	14	0	0	13	21	
Totalt	10	39	25	34	22	54	34	13	8	17	11	.000
	30	43	21	82	40	31	15	3	1	44	22	

Table 3.2.7. The number of different behaviour categories in the introductory phase in periods 1-4 in the behaviour studies of haddock.

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baits in the fourth period. There was, however, no unambiguous tendency with respect to a changed behaviour in time towards any of the bait sizes ($p>0.350$, Chi - square test applied on the contingency table of each individual behaviour categories and total number of categories in each period; Ih was not tested), and the behaviour of the haddock in the introductory phase was therefore evaluated on the basis of the overall material. There were no differences in the shares of approaches towards 10 and 30 g baits. The high frequency of sniffs towards 30 g baits ($p=0.001$) shows that the behaviour towards this bait size was more inhibited than towards 30 g baits. This is also underlined by the fact that the frequency of haddock that sucked the 10 g baits completely in was more than twice as high as for 30 g baits ($p<0.001$). The frequencies of partly sucking in was highest for 10 g baits ($p=0.001$), while the share of bite over the bait was highest for 30 g baits ($p=0.010$).

The results from the attack phase are presented in Table 3.2.8. Pulling and chewing has been left out of the statistical analyses. From the table it can be seen that there was a significant difference in the behaviour towards 10 and 30 g baits both in the first and second periods, while it evened out in the third and fourth. The difference in the first half of the studies consisted in that a much larger part of the haddock that attacked 30 g baits jerked ($p=0.001$), while weak jerks ($p=0.001$) and chewing ($p=0.042$) occurred more often towards 30 g baits. The share of spurts was about the same for both bait sizes. It is otherwise interesting to note that as learning took effect, the frequencies of weak jerks (Rs), pulling (D) and chewing (Ty) declined so that the change in behaviour was more in the direction of more intensive movements in the attacks (R and Sp). Towards 10 g baits the behaviour changes chiefly manifested themselves (p.82) as increases in the frequency of jerks, while the behaviour of the haddock towards 30 g baits changed little during the trial period.

Tabell 3.2.8. Antallet av de ulike atferdskategoriene i angreps- og avslutningsfasen i periode 1 - 4 i atferdstudiene med hyse.

Per-iode	Agn Bait (g)	Attacking phase Angrepsfase											Avslutn	
		Rs		R		Sp		D		Ty		p	U	F
		Nos. Ant.	% Pro.	Ant.	Pro.	Ant.	Pro.	Ant.	Pro.	Ant.	Pro.			
1	10	9	23	6	15	15	38	5	13	4	10	.009	17	5
	30	4	9	22	47	16	34	4	9	1	2		23	2
2	10	11	32	8	24	12	35	1	3	2	6	.014	19	3
	30	1	5	12	57	7	33	1	5	0	0		11	2
3	10	4	17	7	30	11	48	0	0	1	4	.568	17	2
	30	3	11	12	44	11	41	1	4	0	0		17	1
4	10	1	3	16	44	17	47	17	3	1	3	.980	16	
	30	1	4	13	48	13	48	0	0	0	0		20	1
Tot.	10	25	19	37	28	55	42	7	5	8	6	.001	69	
	30	9	7	59	48	47	39	6	5	1	1		71	

Table 3.2.8. The number of the different behaviour categories in the attack- and concluding phases in period 1-4 in the behaviour studies.

Table 3.2.9. The number of attacks (Sn+I+Id+Ib) and mean number of attacks per minute in the first and second parts of the behaviour studies with haddock.

	10 g baits Numbers	10 g baits Mean	30 g baits Numbers	30 g baits Mean
First half	64	3.11	72	1.93
Second half	54	0.97	88	1.97

The concluding phase is presented in the right part of Table 3.2.8. A total of 16 haddock were caught on 10 g baits contrasted with 6 on 30 g baits. As almost all of the hookings followed complete sucking-in, the hooking probabilities were calculated on the basis of the sucking-in frequency (ie the ratio between catch and the number of sucking-ins). On 10 g baits it was 0.30 vs 0.19 on 30 g baits. However, the difference was not significant (p=0.230, the binomial test).

The number of attacks (Sn+I+Id+Ib) and average number of attacks per minute in the first and second part of the studies are presented in Table 3.2.9 (period 1 and 2 against period 3 and 4). In the first half there were considerably more attacks towards 10 g baits than 30 g (p=0.009, the binomial test; the expectation is calculated on the basis of the trial period). In the second half the number of attacks per time unit went down considerably towards 10 g baits (p<0.001), while there were almost no change towards 30 g baits. The attack frequency towards 30 g baits was in the second half higher than that towards 10 g baits (p<0.001).

A total of 22 cod were also held together with the haddock and were part of the trials. Due to the great problems experienced with these fish, the results are not presented. Still, an interesting difference in the behaviour of these species was noted. When cod attacked hook and bait, the attacks were almost always directed downwards, and after hooking the fish remained under the line. All attacks by the haddock were, however, directed upwards and they always remained above the hook after hooking. Corresponding behaviour of cod and haddock were observed during avoidance studies in the opening of bottom trawls MAIN & SANGSTER 1981). The cod tried to avoid the trawl by moving towards the bottom, while the haddock swam up and often escaped over the trawl.

Briefly summarized the results show that haddock behaviour was more inhibited towards 30 g baits than 10 g baits. The (p.83) difference was expressed by a larger number of the haddock sniffed and bit over towards 30 g baits, while they often completely sucked in 10 g baits. In addition, the attack frequency in the first half of the studies was higher towards 10 g baits. In the attack phase the difference consisted in that 30 g baits were attacked with higher intensity. The change in behaviour over time towards 10 g baits was manifested by lower attack frequencies and higher intensity in the attacks. However, there was little change in haddock behaviour towards 30 g baits.

Discussion.

A typical behaviour sequence towards 30 g baits consisted in the haddock biting over the bait followed by a hard jerk or a spurt. The reason for this behaviour is possibly connected with the fact that 30 g baits are too large for haddock since they have a very small mouth, and that they try to pull the bait apart. That fish will attempt to divide up food particles that are too large was observed by BRAWN (1969). It is interesting in this connection that there were no differences in selectivity between the two different bait sizes in the catch of haddock in the Vardö trials. It can therefore appear that the haddock does not select prey animals in the same manner as cod. The reason for this could possibly be that haddock will attempt to divide up food particles that are too large, while cod with a much larger mouth than haddock, only attacks food particles that from the start have an acceptable size.

Another interesting result is the development in the attack frequencies per unit time towards the two bait sizes. In the first half of the studies the attack frequency was considerably higher towards 10 g baits than 30 g baits, while it in the second half was higher towards 30 g baits. This result indicates that haddock, like cod, to a limited degree transfer experiences from one bait size to another.

By comparing the results of the behaviour studies and the fishing trials, some interesting connections appear. In the (p.84) first instance, the higher frequency of sniffs towards 30 g baits gives a reasonable explanation of the differences in the catch of body-hooked haddock in some of the fishing trials (see Table 2.3.18). Most of the body-hooked haddock were hooked in the head area and comprised a larger part of the catch on 20 and 30 g baits than 10 g. Otherwise there were indications in the fishing trials that fewer fish attacked large baits than small. This result was also corroborated by the behaviour studies in that fewer haddock attacked 30 g baits than 10 g baits in the first half of the studies. In addition, the correlation analyses showed that the haddock contributed to half 20 and 30 g baits, but not to half 10 g baits, This also agrees with findings from the behaviour studies in that the haddock to a greater degree tore 30 g baits apart by biting over the bait and then jerked or spurted.

3.2.3 Comparison of behaviour in the laboratory and in the field.

A number of authors have pointed out that if the fish attacks the line repeatedly, it could be a possible source of error in comparative fishing trials (HAMRE 1968, HUSE 1979a, FERNÖ *et al* 1981, FERNÖ & HUSE 1983). The behaviour studies alone do not give a basis for deciding if repeated attacks occurred during the fishing trials. But if the behaviour studies are compared with observations in the field, it is possible to a greater degree to understand and also make the behaviour of the fish more probable.

A bait that is hanging from a line is obviously an unusual prey for the fish. When a fish attacks the line and in addition can feel the point of the hook, it is reasonable to assume that it will lead to a modification of the behaviour as the results of the behaviour studies clearly showed. The correlation analyses showed that cod in the Vardö area did not affect half baits, which is the most likely bait condition (status) if fish steals bait from the line. This also agrees with the findings that there were no baits found in the cod stomachs. It is therefore not very probable (p.85) that cod attacked the line repeatedly in the Vardö trials.

The correlation analyses showed, however, that the haddock affected half 20 and 30 g baits, but in contrast not 10 g baits. This agrees with the biological studies in that two haddock had 20 and 30 g baits in their stomachs. Both had eaten several baits which shows that haddock attacked 20 and 30 g baits repeatedly. On the other hand it is not very likely that haddock attacked 10 g baits repeatedly. This agrees with the results of the behaviour studies in that haddock quickly modified their behaviour towards 10 g baits, while there was no change in the behaviour towards 30 g baits. The correlation analyses showed, however, that haddock only to a small degree affected half 20 and 30 g baits so that the frequency of repeated attacks was probably relatively low also towards these bait sizes.

In the Gryllefjord trials the correlation analyses showed that the cod affected all bait status categories. There were also found bait in the stomachs of over 10 percent of the cod, and in several cases there were baits of another type (squid bait) than the type the cod had been hooked on (mackerel bait). It therefore seems to be obvious that the cod in the Gryllefjord area attacked the line several times. The results are , however, too doubtful to be able estimate the frequency of repeated attacks.

4 CONCLUDING DISCUSSION

(p.86)

Most longline studies are insufficiently described and usually do not meet scientific requirements for reproducibility (HÖEG 1971). Many authors have for example given the hook type by only calling it a Mustad hook with a size indication without giving the type. Up to a few years , O.Mustad & Son Ltd. produced about 120,000 different types and sizes of hooks (PAULSEN & ROBERTSEN 1980). There is in addition no system in the numbering of the hooks so that it is practically impossible to know what type of hook has been tested. Another problem is that the bait size almost never is specified, and often it is not even mentioned what type of bait has been used. In a number of studies the catching ability of the experimental parameters has only been measured in number of fish (catch rate) without relating it to size. Many of these studies are of little value since the differences in catches could just as likely be due to selectivity differences between the parameters rather than that they have a differing effectiveness. Fishermen are not paid for the number of fish they catch, but rather for the weight they bring in.

In the introduction it was pointed out that there are some conflicting results in longline research. Some of these differences could possibly be hidden in the poor description of the experiments. Poor descriptions make it almost impossible to draw parallels with the work of other authors. The demand for standardization of longline experiments is therefore strong.

4.1 EXPERIMENTAL SETUP FOR COMPARATIVE FISHING TRIALS.

A possible source of error in comparative fishing trials could be the experimental setup if it differs much from usual longline fishing. The methods most used have been tub-against-tub and hook-against-hook comparisons. In addition, paired comparisons of cells have also been used by some, a method that is something in (p.87) between the two mentioned above. Paired comparisons of tubs is the experimental setup that would be closest to real fishing situations. The greatest disadvantage of this method is that it is sensitive to uneven distribution of fish in the sea due to the great length of longline usually found in a tub. The method is especially not very good at low fish concentrations when spotty fish distribution could skew the results considerably. To obtain a reliable estimate of the difference in effectivity, a large volume of experimental results is needed. On the other hand, the tub-against-tub comparison will give the most accurate estimate if the experimental volume is large enough.

In the use of hook-against-hook comparisons, uneven distribution of fish will not matter. The greatest disadvantage of this method is that it is not very realistic. In the regular longline fishery the fish will only have an opportunity to attack one parameter, while in a hook-against-hook comparison it could be able to attack two. In a number of studies different factors have been pointed out that could contribute to both over- and under estimation of the catch difference with this experimental setup (HAMRE 1968, HUSE 1979a, FERNÖ et al 1981, FERNÖ & HUSE 1983). These factors fall into two categories: (1) Overestimation of any catch differences as a result of the fish attacking the line several times, and (2) underestimation due to saturation.

(1) The reason for believing that repeated attacks could lead to overestimation of the catch differential can be illustrated with an example. We have two hooks with a large difference in effectivity. A fish that bites on the poorest hook without being hooked can in the next instant attack the more effective neighbouring hook and be hooked on this. If only hooks of the least effective type had been used, the fish could still be hooked by attacking repeatedly. That this danger could be real has been underlined by the fact that BJORDAL (1982) during hook studies in the near- and offshore longline fishery for ling found that hook - against- hook comparison gave a considerably higher estimate of the catch

differential than paired comparisons of cells. (p.88).

(2) Saturation is obviously a much greater danger with this experimental setup than with the others since saturation can occur within a few hooks. The larger the difference is in the effectivity of the experimental parameters, the greater is the danger of saturation.

These factors will be able to affect the estimated catch differences, but hook-against-hook comparison will still quickly disclose any effectivity differences between the parameters. The result of the hook-against-hook comparison of 10 and 20 g baits in this problem gave the same catch differential for haddock as paired comparison of cells. This shows that hook-against-hook comparisons in some cases can also give useful measurements of the effectivity differences.

A more serious objection against hook-against-hook comparison which is not described in the papers cited above, is that saturation can lead to overestimation of any selectivity differences between the parameters. This can in turn lead to wrong conclusions with respect to the effectivity of the parameters for fish in different length intervals. This can be illustrated with an imaginary example. We have two hook types, A and B, which are equally effective for fish over a certain length L, while A is considerably more effective for fish over a length L, while A is considerably more effective than B below L. By fishing in an area where most of the fish are smaller than L, saturation will lead to a situation where the small fish will occupy the A-hooks, so that the B-hooks will be able to catch more large fish than A. In this manner the mistake could be made to conclude that hook A is less effective than hook B for fish that are larger than L.

Hook-against-hook comparison is therefore only applicable if it could be assumed that there are no selectivity differences between the experimental parameters. The method will then quickly disclose any differences in effectivity, but gives on the other hand no basis for estimating the exact magnitude of the (p.89) differences.

Paired comparisons of cells is a compromise between the two other experimental setups. This method is relatively realistic, requires a relatively small experimental volume and makes it possible to enter the hook codes directly into a portable mini terminal (Section 2.1.6). Seen in relation to hook-against-hook comparison, from a purely practical point of view it is much easier to implement this method. To a certain degree it is also possible to control any sources of error. For example, if there are selectivity differences between the experimental parameters, saturation can be revealed by studying the sizes of fish in cells with differing catch rates as was done in the bait comparisons for cod in the Vardö trials. The distribution of catch in relation to the "poles" and floats in the Gryllefjord trials shows, that with this experimental setup, one must be observant of the fact that not all parts of the longline are equally effective. The number of hooks in the cells should be adjusted to the individual fishery. However, the cell size should not be brought down too far since it would make the experimental setup less realistic. By intuition it appears as if 10 hooks and a cell length of 25 metres would be the absolute minimum.

Which experimental setup should be used under different conditions depends on the objective of the studies. Paired comparison of tubs is the most realistic experimental setup, and therefore gives the best estimate of any difference between the parameters. However, the method requires a very large experimental volume. Hook-against-hook comparison is a method that will quickly give an answer if the parameters have different effectivity, but is not suitable to estimate the magnitude of the differences. An assumption for using this method is that there are no differences in selectivity between the parameters; something that can not usually be assumed in advance. Cell-against-cell comparison is an experimental setup that requires a relatively small experimental volume and which at the same time is relatively realistic. This method is therefore to be preferred in most cases.

4.2 THE HOOK COMPARISONS. (p.90)

In the Vardö trials hooks nos. 4 and 5 were more effective than hook no. 6 both for cod and haddock, while hooks nos. 6 and 7 were approximately equally effective (hook no. 6 is standard in the area). The hook size had very little effect on the selectivity both for cod and haddock. Furthermore, the bait size had little effect on the relative catch differences between the hooks for cod, while it was of great importance for haddock in that hooks nos. 4 and 5 only were more effective than hook no. 6 with 10 g bait. The results indicate that neither cod nor haddock attacked the line repeatedly to any great extent in the Vardö trials. The greatest danger for mistakes in the estimated catch differences with an experimental setup with every second hook, therefore consists in that they could have been underestimated as a result of saturation. Greatest is the danger in the comparisons with 10 g baits since the highest catches were made on this bait size. The aim of these studies was, however, not to determine the exact efficiency differences between the different hooks, but to decide which hook is best. However, it should be taken into consideration that the observed catch differences could be somewhat underestimated.

In the Gryllefjord trials the results were not quite unambiguous. The tendency was , however, the same as in the Vardö trials in that smaller hooks were more effective than larger hooks. The catch rates were relatively low so that saturation probably did not occur. On the other hand it could be imagined that the catch differences were somewhat overestimated since the cod in this area probably attacked the line repeatedly.

The results of the Vardö- and Gryllefjord trials showed that there were probably different factors that decided the effectiveness of the hooks in the two areas. In the Vardö trial the results indicate that it was the penetrating ability of the hooks that was of greatest importance for the effectiveness both for cod and haddock, and that the penetrating ability in turn depends on the width of the barb. However, for haddock a hook with a (p.91) small barb (hooks nos. 4 and 5) was only more effective with 10 g baits. An interesting observation was in this connection made during the behaviour studies. It appeared that haddock attacked 30 g baits with considerably more intensity than 10 g baits. The results of the bait status analyses indicate that this was also the case in the field trials in that the haddock affected half 20 and 30 g baits, but not 10 g baits. The reason for there being no difference in catch between the hook sizes with 20 and 30 g baits could therefore be that haddock attacks these baits with such high intensity that the penetrating ability was not decisive for the hooking.

In the Gryllefjord trials the results indicate that it was probably the hooking point in the fish that was of greatest importance for the effectivity. It is interesting to note in this connection that the cod in this area affected the different bait status conditions, while the cod in the Vardö area only affected clean hooks (probably indirect affect). It can therefore appear as if the intensity in the attacks have been higher in the Gryllefjord area, a finding that would give reasonable explanation for the penetrating ability not being of such great importance.

It is difficult to say what could have been the reason that the hooking point was of no great importance in the Vardö area. It could possibly be due to different cod behaviour in the two periods. Another possibility is that the catch situation could have been different. For example, the catch rates were relatively low in the Gryllefjord trials so that hooking to a greater extent could have been dependent on the activity of the fish itself, while the activity of other fish could be imagined to be an important reason for hooking in the Vardö area.

It is unfortunately only in exceptional cases possible to carry out comparisons with other studies due to the fact that the hook type is usually not given. HUSE(1979a) has reported that a hook where the sharp tip points towards the hook eye (Mustad Wide Gap no. 5, the WG hook) caught more cod and haddock than (p.92) the standard hook (no. 6) in the Vardö area. On the basis of behaviour studies he assumed that the behaviour patterns jerk and spurt formed the basis for hooking, and since the force in these behaviour patterns was very high, he furthermore assumed that hooking will depend on if the tip of the hook will come in contact with different parts of the fish mouth (for example the corner of the mouth). The results in this study indicate, however, that other behaviour patterns can lead to hooking, for instance the activity of earlier hooked fish. It also turns out that the better catching ability of the WG-hook can be explained wholly or in part based on the penetrating ability. The width of the barb is less on the WG-hook than in a standard hook (3.2 mm on WG-hook against 3.8 on the standard hook). In addition, almost all force in the gangion will contribute to the hooking with the WG-hook, while 15-20 percent of the force will be lost with the standard hook (see Fig. 2.2.10 on the angle of attack of the hook). The penetrating ability of the WG-hook is therefore likely about the same as for hook no. 5 (barb width 2.7 mm) which gave approximately the increase in catch as HUSE found for the WG-hook. It is also interesting that the WG-hook did not give a significant catch increase when it was tested on cod ready to spawn in Lofoten, something that could be caused by the spawning cod attacking the line with higher intensity.

The results of the hook studies show that one must consider both the penetrating ability and the hooking point in the design of a hook to be as effective as possible. The penetrating ability can be improved by having the sharp tip of the hook point towards the eye, but the biggest potential lies in the reduction of the width of the barb. The size differential existing in the width of the barbs of the hooks tested did not have any effect on the ability of the hook to hold the bait. This could also apply to the ability of the hook to hold the fish. With respect to the hooking point, the gap of the hook is probably of the greatest importance. What the most favourable size would be is somewhat uncertain. The results in Gryllefjord indicate that a relatively small gap would be most effective.

The results otherwise indicate that hook size is not a suitable parameter for regulating the longline fishery for (p.93) cod and haddock with the aim of reducing the catch of small fish.

4.3 THE BAIT COMPARISONS

The difference in the size of the cod in the Vardö- and Gryllefjord trials was very large. There was, however, an overlap between the size distributions. in that the upper half of the Vardö trials fall together with the lower half of the Gryllefjord trials. This overlap makes it possible to carry out some interesting comparisons of the results.

In the Vardö trials the bait sizes had an effect on the selectivity. Small baits were more effective for smaller fish, while there were indications that small and large baits were about equally effective for the large cod between ca 60 and 70 cm. In other words, this means that the baits had equal selective properties in this length interval. This is supported by the results in Gryllefjord in that the bait size had little influence on the selectivity of fish over ca 55 cm in spite of a large spread in the sizes of the catch (55 - 115 cm) and large differences in the sizes of the baits tested. The results of the bait comparisons therefore indicate that the bait sizes largely only affect the left side of the selectivity curve. An interesting result in this connection has been reported by McCRACKEN (1963) from the bottom longline fishery for cod off Canada. In an experimental setup where he adjusted the bait size to the hook (ie large bait on large hook and small bait on small hook), he found that the combination of small hook and small bait caught considerably more small fish than large hook and large bait, but that the combinations were equally effective for fish over a certain length. If it is assumed that there were no differences in the selective properties of the hook sizes that he was experimenting with, which seems to be reasonable seen on the background of the hook comparisons in this study,(p.94)

McCRACKEN's study also shows that the bait size can affect the left side of the selectivity curve.

It is known that fish select prey animals on the basis of body size (WINDELL 1978), and that physical dimensions limit the size of the prey animals upwards (WANKOWSKI 1979). The reason for the selectivity differences between the different bait sizes is therefore probably the preference of the fish with respect to the size of the food particles, something that is also supported by the behaviour studies in that fewer fish attacked large baits than small.

Another important result following from the comparison of the results in the two experimental periods is that the relative effectivity differences between different bait sizes could vary from fishery to fishery. The reason for this is that the effectivity of 10, 20 and 30 g baits was about the same for fish over ca 60 cm in the Vardö trials, while 10 g baits were less effective than both 20 and 40 g baits for fish in the same length interval in the Gryllefjord trials.

There could be several reasons for this.Large baits could for example have a better olfactory attractiveness than smaller baits (ie odour attractant), and that this was of greater importance in Gryllefjord than in Vardö. The Vardö trials were carried out about midsummers, while the Gryllefjord trials were held in late winter. It could therefore be imagined that visual stimuli could have been of greater importance in Vardö. Another possibility is that the choice of preference of the fish with respect to the size of the food particles could perhaps be variable throughout the year.

For haddock the bait size had little effect on the selectivity. On the other hand it was of great importance for the effectiveness in that small baits were considerably more effective than larger baits. If different bait sizes have different alluring properties, either olfactory or visually, there is reason to believe that the relative difference in effectiveness between different bait sizes could also fluctuate for haddock. (p.95)
It is therefore not for certain that small baits will be more

effective under other conditions. The results could still probably be generalized for the floating longline fishery which is the only commercial fishery especially directed at haddock. The floating longline fishery is carried out in the summer along the coast of East Finnmark under approximately the same conditions as these fishing trials.

The behaviour studies indicated that the reason that bait sizes affected the selectivity for cod , but not for haddock, is that cod only attacks food particles that initially has the correct size, while haddock attempt to break up food particles that are too large.

That the bait size only appears to affect the left side of the selectivity curve for cod, raises a number of interesting perspectives. The catch of small fish could, for example, be reduced by increasing the bait size. This could be an advantage for fishermen in that hooks will be vacant for larger fish which could increase the weight of the catch. From a resource point of view it is important that the young fish are spared. If the fishery is being carried out in areas with only large fish, the bait size could in many fisheries be reduced without loss of catch, and in some cases this could in addition result in increased catches, such as for haddock in the Vardö trials. The bait consumption in 1981 was about 16,000 t fish that could be used for food, at a value of almost 90 million kroner, of which 57 million were governmental subsidies (ANON 1982). It is therefore obvious that only small reductions in the bait consumption could result in large economic benefits.

Another result that raises interesting perspectives is the bait status analysis in the Vardö trials (the Gryllefjord trials are not mentioned here due to the uncertainty in those results). On the basis of a number of behaviour studies of different species of fish in front of hooks and baits, an impression has been formed that longline is not a very effective gear. The work has therefore to a large extent been directed towards improving the (p.96) effectivity of the hook. As a result, hook types have been developed that are more effective than the traditional hooks. The results of the bait status analyses showed, however, that there is reason to assume that the effectiveness of "poled" longlines in the Vardö area is considerably higher than earlier believed. It could therefore be that the greatest potential for making the longline fishery more effective consists in getting more fish to attack hook and bait. This could be achieved by developing baits that would attract fish more efficiently. The results of the behaviour studies indicate that the reason for large baits being less effective than small baits was that both cod and haddock to a lesser degree attacked large baits. It could therefore be imagined that there would be a large potential in getting more fish in the area around the longline to bite on the hook.

5 SUMMARY

(p.97)

Fishing trials were carried out in two periods: In June 1980 in the Vardö area and in February/March 1981 on Sveinsgrunnen bank northwest of Senja (the Gryllefjord trials). In addition, studies of the behaviour of cod and haddock towards baits of various sizes were done in the laboratory.

In the Vardö area, Mustad Norway hooks (quality 7269) nos. 4,5,6,and 7 and mackerel bait of 10,20 and 30 g were tested (hook no. 6 and 20 g baits are standard in the area). The catch consisted principally of cod and haddock.

For cod hooks nos. 4 and 5 were more effective than hook no. 6, while hooks nos. 6 and 7 were about equal. The different hook sizes had approximately the same selective properties. The bait size had little effect on the relative differences in effectiveness between the hooks. The width of the barbs was isolated as the most likely reason for the observed differences in catches.

The results for haddock were largely in agreement with the results for cod. However, for haddock it was only with 10 g baits that hooks nos. 4 and 5 were more effective than hook no.6.

In the Gryllefjord trials , hooks nos. 5, 6 and 7 and mackerel baits of 10, 20 and 30 g were tested. The catch consisted chiefly of cod (skrei) on their spawning migration to Lofoten. The results of the hook comparisons were not completely unambiguous, but similarly to the Vardö trials , there was a tendency to smaller hooks being more effective than larger hooks, and that the different hook sizes had approximately the same selective properties. The results indicate that it was the hooking point in the mouth that was of the greatest importance for the observed differences in effectiveness.

The results of the bait comparisons for cod indicate that the bait size only affects the left side of the selectivity (p.98) curve. In the Vardö area, 10, 20 and 30 g baits were about equally effective for cod over ca 60 cm, while smaller baits were more effective for fish under this length. The behaviour studies showed that the effectivity differences probably are caused by more cod attacking small baits than large.

In the Gryllefjord trials, 20 and 30 g baits were about equally effective, while the effectiveness of 10 g baits was somewhat lower. The results therefore show that the relative effectivity differences between different bait sizes can vary from fishery to fishery. The data did not give any basis for establishing what could be the reason for the variations.

The bait size had little influence on the selectivity in the fishery for haddock in the Vardö area. On the other hand, it was of great importance for the effectiveness in that 10 g baits were considerably more effective than 20 g baits, which in turn were more effective than 30 g baits. The behaviour studies indicate that the most important reason for the differences in effectivity was that more haddock attacked small bait than large.

Different forms of experimental setups in comparative fishing trials with longlines were evaluated. In most cases it is likely that paired comparisons of cells would be the best experimental setup (with for example 50 hooks per cell), as it requires a relatively low experimental volume and gives an approximately realistic picture of differences, if any, between the experimental parameters.

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APPENDIX A

Bait status analyses - the Vardö trials.

How the correlation analysis functions between the various bait status, can be illustrated with some examples (the results of the analysis are presented in Table 2.4.1). We have 50 cells with 50 hooks in each. In one cell a total of 10 fish have been caught (catch rate =0.2), and of the 40 remaining hooks there are half baits on 20, which gives the point (0.2, 0.5). In another cell there is a catch of 40 fish, and there are 5 half baits on the 10 remaining hooks. This combination gives the point (0.8, 0.5). The line between the points will be parallel with the abscissa (no correlation). If there had been 5 half baits in both cells, we would get the points (0.2, 0.125) and (0.8, 0.5), which gives a line with a positive gradient (positive correlation). These examples show that even if the fish to a limited extent affects the bait status, or that the effect for example decrease somewhat with fish density, the method could still reveal the effect of the fish.

The assumption used as a basis for utilizing linear correlation analysis is that the sample is bi-variably normally distributed (ZAR 1974). This is not fulfilled as the samples consist of fractions between 0 and 1. The data were therefore converted with the help of an arcus - sinus transformation. Another objection to the method is the dependence between variables. When for example the catch rate increases, the number of hooks without catch decreases, which implies that few remaining hooks will have as large weight in the analysis as cells with low catch rates. However, there were in no cases less than 10 hooks remaining so that probably has not been of such great importance.

In Table A.1 the results from another method of analysis are presented. The data are from Trial 64, Trial 65 and Trial 67 in the Vardö trials. The table shows the frequencies of the different bait status in cells with many and few fish (this method is therefore in principle the same as the correlation analysis). (p.109)

From the table it can be seen that the share of clean hooks on the various bait sizes was highest in cells with much fish. The share of half and whole baits was on the other hand at times less in cells with much fish.

In Table A.2, Table A.3 and Table A.4 the results of a third method of analysis is presented. This method is based on that the fish distribution in the sea is spotty. If one or more fish have been hooked at one part of the line or another, it is reasonable to assume that the probability for the empty hooks being attacked is less the further away from the hooked fish we are. If the fish affect the bait status, it will probably manifest itself in greater wear and tear on the hooks nearest the hooked fish. The tables show that the share of clean hooks decreased with increasing distance from hooked fish, while the share of half and whole baits in part increased. (From Table A.2 it can be seen that the number of clean hooks was considerably lower on the hooks located furthest from hooked fish than in the other hook positions. It is, however, no reason to put any weight on this result since these data are from a single setting).

The results of these analyses are therefore in agreement with the correlation analyses.

Table A.3. Number of the different bait status relative to hooked fish in cells with 20 g baits. Position 1 is the hook closest to the hooked fish. The material is from Trials 64, 65 and 67, the Vardö trials.

Hook position	Blank hooks		Half baits		Whole baits	
	Nos.	%	Nos.	%	Nos.	%
1	463	23	1228	62	302	15
2	133	18	464	60	171	22
3	52	16	201	60	82	24
4	34	19	109	63	31	18
≥ 5	56	15	219	61	86	24

Table A.4. Number of the different bait status relative to hooked fish in cells with 30 g baits. Position 1 is the hook closest to the hooked fish. The material is from Trials 64, 65 and 67, the Vardö trials.

Hook position	Blank hooks		Half baits		Whole baits	
	Nos.	%	Nos.	%	Nos.	%
1	345	19	964	52	540	29
2	165	17	514	52	308	31
3	77	14	291	53	184	33
4	50	15	172	53	106	32
≥ 5	100	13	382	52	260	35

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